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DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
JOSEPH A. HOLMES, Director

FUEL-BRIQUETTING INVESTIGATIONS

JULY, 1904, TO JULY, 1912

BY

C. L. WRIGHT

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FUEL-BRIQUETTING INVESTIGATIONS, JULY, 1904, TO JULY, 1912.

By C. L. Wright.

INTRODUCTION.

In 1904 the Government began a series of fuel-testing investigations at its fuel-testing plant at St. Louis, Mo. These investigations, which were placed under the supervision of the United States Geological Survey, included chemical analyses, steaming tests, gas-producer tests, briquetting tests, coking tests, and washing tests of samples collected from the various coal fields of the country. The specific purpose of the investigations was to analyze and test the coals and lignites in the United States, in order to determime their fuel values and the most efficient methods of utilizing them for different purposes.

Part of the fuel-testing plant, including the briquetting equipment, was moved to Norfolk, Va., in 1907, and the fuel-testing investigations were made one of the divisions of the technologic branch of the Geological Survey. In 1908, after the close of the Jamestown Exposition, most of the fuel-testing equipment was removed to its present location at the Pittsburgh experiment station, Fortieth and Butler Streets, Pittsburgh, Pa. In 1910, an act of Congress, effective July 1, established the Bureau of Mines in the Department of the Interior and authorized the transfer to this bureau of the fuel-testing investigations that had been carried on by the technologic branch.

Bulletins presenting the results of various inquiries and investigations relating to briquetting have been published by the Geological Survey and the Bureau of Mines.[a] As the supply of some of these bulletins is exhausted, the Bureau of Mines has decided, instead of reprinting them, to publish the more important facts they contain and the results of all other briquetting investigations undertaken by the Government from July 1, 1904, to July 1, 1912, in one volume. Material from other bulletins containing reports of steaming tests of briquets is included, due credit in each case being given.

---

[a] Parker, E. W., Holmes, J. A., and Campbell, M. R., committee in charge, Preliminary report of the operations of the coal-testing plant at the Louisiana Purchase Exposition, St. Louis, 1904: U. S. Geol. Survey Bull. 261, 1905, 172 pp.; Holmes, J. A., Preliminary report on the operations of the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., 1905: U. S. Geol. Survey Bull. 290, 1906, 240 pp.; Parker, E. W., Holmes, J. A., and Campbell, M. R., committee in charge, Report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904: U. S. Geol. Survey Prof. Paper 48, 1906 (in three parts), 1492 pp., 13 pls.; Holmes, J. A., Report of the United States fuel-testing plant at St. Louis, Mo., January 1, 1906, to June 30, 1907: U. S. Geol. Survey Bull. 332, 1908, 299 pp.; Mills, J. E., Binder for coal briquets (investigations made at the fuel-testing plant, St. Louis, Mo.): U. S. Geol. Survey Bull. 343, 1908, 56 pp. (reprinted as Bull. 24, Bureau of Mines); Wright, C. L., Briquetting tests at the United States fuel-testing plant, Norfolk, Va., 1907–8: U. S. Geol. Survey Bull. 385, 1909, 41 pp., 9 pls. (reprinted as Bull. 30, Bureau of Mines); and Wright, C. L., Briquetting tests of lignite at Pittsburgh, Pa., 1908–9, with a chapter on sulphite-pitch binder: Bull. 14, Bureau of Mines, 1911, 64 pp., 11 pls., 4 figs

GENERAL EQUIPMENT OF GOVERNMENT FUEL-TESTING STATIONS.

The equipment for carrying on briquetting tests at the St. Louis fuel-testing plant consisted of three briquetting plants—one exhibited by William Johnson & Sons, of Leeds, England; one by the American Compressed Fuel Co., of Chicago, Ill.; and one by the Renfrow Briquet Machine Co., of St. Louis, Mo. These presses or plants are referred to in the text as the "English machine," the "American machine," and the "Renfrow No. 1 machine." A building was provided for the English plant and another for the American plant. Steam and electric power were furnished by the power plant of the station. A direct-heat cylindrical drier contributed by the C. O. Bartlett & Snow Co., of Cleveland, Ohio, was used for drying the washed coals and lignites when the moisture content was too high to permit successful briquetting. A Williams crusher contributed by the Williams Patent Crusher & Pulverizing Co., of St. Louis, Mo., and a Stedman pin disintegrator made by the Stedman Foundry & Machine Works, of Aurora, Ind., were used for reducing the fuel and binders to sizes suitable for briquetting.

The equipment used for briquetting experiments at the Norfolk plant consisted of the English plant used at St. Louis, a new Renfrow machine designated in this report as the "Renfrow No. 2," and a Schlickeysen "auger" machine for manufacturing "machined peat."

At the Pittsburgh plant the English machine was placed on a foundation, but auxiliary equipment for it has not yet been installed, and most of the briquetting experiments at this station have been made with the German lignite-briquetting plant, complete with press, drier, and cooler. A small hydraulic caking press made by the Watson-Stillman Co. of New York, and operated by hand, was also installed at this station and used for making preliminary briquetting tests of fuels and comparative tests of binders.

PERSONNEL OF BRIQUETTING STAFF.

The various fuel investigations at St. Louis in 1904 were under the general supervision of E. W. Parker, statistician of the Geological Survey; J. A. Holmes, then State geologist of North Carolina; and M. R. Campbell, geologist of the Geological Survey. This committee, with the addition of C. W. Hayes, then chief geologist of the Geological Survey, also had charge of the work in 1905. Since early in 1906 the work has been under the general direction of J. A. Holmes, now director of the Bureau of Mines.

The briquetting tests at St. Louis were originally directed by J. H. Pratt, of the University of North Carolina, assisted by A. A. Steel. Later the tests were placed in charge of C. T. Malcolmson, who was assisted by J. E. Mills, W. J. Chapman, Robert Strasser, G. E. Ryder, Ralph Galt, and C. L. Wright. The tests at Pittsburgh were directed by C. L. Wright, assisted by H. L. Gardener and Otto Lehman. Acknowledgement is gratefully made of valuable advice and suggestions from H. M. Wilson, A. W. Belden, O. P. Hood, and J. C. Roberts.

The chemical analyses were made at the laboratory of the fuel-testing division under the direction of F. M. Stanton and, later, A. C. Fieldner.

COMMERCIAL ASPECTS OF BRIQUETTING IN THE UNITED STATES.

There are some American engineers who doubt whether fuel briquetting can be successful in the United States for many years to come. This skepticism probably is caused by the numerous unsuccessful attempts to briquet fuels on a commercial scale.

CAUSES OF FAILURE OF BRIQUETTING PLANTS.

The failures mentioned were in a large measure due to the following causes:

1. Many of the "plants" represented promoters' schemes, no attempt being made to build the plants.

2. Attempts were made to develop a new binding material or a new press, without proper appreciation of the principles of briquetting.

3. Plants were poorly situated for marketing the briquets.

4. The briquets produced were inferior. Briquets containing an excessive amount of pitch binder have been placed on the market, with the result that after one trial householders were disgusted with the soot and odor produced. Results of this kind are especially harmful to the development of the industry, as it is very hard to overcome a prejudice against briquets when once it is created.

5. Poor salesmanship has been responsible for other failures of briquetting ventures. As briquets are a comparatively new and untried form of fuel careful salesmanship to introduce them is required. As many retail coal dealers are afraid that the new fuel will supplant the usual fuels they do not encourage the introduction of briquets; some even tell their customers that briquets are made of dirt and have practically no heating value. Therefore, to build up a successful business in fuel briquetting requires much advertising and demonstration, not to mention capital and time.

6. Uncertainty in the supply of raw fuel or binder has caused the failure of many briquetting plants.

7. Lack of technical supervision has in some instances been the direct cause of failure. Certain features of briquetting, notably suitable binder, proper temperature, and the influence of moisture, are all problems that require technical investigation and chemical control. The making of satisfactory briquets involves considerably more than the possession of suitable machinery. Slight variations in the quality of binder used may make all the difference between success and failure, as the binder is the largest item in the briquetting cost.

CONDITIONS FAVORING DEVELOPMENT OF THE INDUSTRY.

The condition that more than any other has prevented the development of this industry in the United States is the low price of bituminous coal and especially the small difference between the price of the lump coal and that of the slack, or fine coal. Much of the lump coal is finally crushed before being manufactured into coke, and the slack coal has even the advantage in not having to be crushed. Where these coals are sold for general power purposes much of the fine coal can be shipped and burned with the lump coal, for the reason that it fuses as soon as it begins to burn, and therefore neither clogs the draft nor escapes with the ashes, as is the case with noncoking coals.

In States where noncoking coals are produced the demand for the slack coal is not so great, and in some places it can be bought for less than 50 cents per ton. At a number of mines large quantities are thrown on the dump as waste, and frequently the slack is burned there in order to get rid of it.

A large variety of special equipment for burning fine coal has been developed in the United States. The results of many tests seem to indicate that with the noncoking coals the use of the finely powdered coal, even in the modern furnace, is a disadvantage rather than a gain. The fine material sifts through on to the grates, prevents a full draft, and may be ultimately lost with the ashes. This material should therefore be separated from the coarser coals and made into briquets if possible.

With anthracite and semianthracite coals the difference between the price of the lump coal and that of the slack is often more than sufficient to cover the cost of manufacturing briquets, and in such cases there can be no question as to the possibility of establishing a briquetting industry as soon as the proper binding material and briquetting equipment can be provided.

There are still other cases in which the difference between the price of the lump coal and of the slack is about sufficient to cover the cost of briquet manufacture. The fact that the briquets made from this material present certain advantages over the lump coal make them command a price enough higher to provide a margin of profit.

The high cost of pitch binder is one of the barriers in the way of the development of this industry. One of the purposes of this investigation has been to discover, if possible, some cheaper binding material. The cost of manufacturing briquets in France, Germany, Belgium, and England, including all necessary items except the cost of the coal and binding material, ranges from 25 to 50 cents per ton. Where pitch is used as a binder, its cost for a ton of briquets varies from 50 to 80 cents. How far the cost of briquetting may be reduced by the use of cheaper binders remains to be seen.

PRESENT OUTLOOK.

The most favorable outlook for the development of this industry in the United States is in the direction of the use of briquets in locomotives and in domestic furnaces and stoves. It can hardly be expected that at the present prices of slack coal briquets can be manufactured for successful use in the ordinary power-plant furnaces.

The fuel-briquetting industry has passed the pioneer stage and is making a steady growth each year. The engineering difficulties have been solved to the extent that at least one engineering firm is willing to build a briquetting plant and guarantee it to produce a specified tonnage of briquets of a certain quality, the plant's efficiency to be established before payment is made.

There were in operation in the spring of 1912 18 fuel-briquetting plants, all of which were visited by the writer; about 6 other plants may be operating successfully, although they were not inspected by the writer in 1912.

ADVANTAGES OF BRIQUETTED OVER NATURAL FUEL.

Briquets when properly made with a suitable binder possess the following advantages over raw fuel:

1. The even size of the briquets permits a more regular and thorough combustion in the firebox or furnace.
2. They produce much less smoke, and, in many cases, practically no smoke. This feature of briquets is more noticeable with the smaller sizes than with the large rectangular blocks. On account of the number of flat surfaces the latter tend to pack together, thus preventing free access of air. If an excessive amount of tarry pitch is used some smoke will be given off.
3. Good briquets retain their shape in the fire, and do not cake sufficiently to cut off the supply of air to the upper surface of the fire.
4. Briquets usually burn to a fine ash without clinkering. In the briquetting process the mixing and grinding distributes the ash or foreign material, which forms lumps and layers in the raw coal. When raw coal is burned many of these lumps and layers, being too large to pass the grate, are fused into clinkers.
5. A briquet fire requires much less care than one of raw fuel.

6. The evaporative power of briquets is greater than that of coal in its natural condition. This advantage has been found to exist at all rates of evaporation.[a]

8. The weather-resisting qualities of many coals, especially lignites, are greatly improved by briquetting.

9. Steam can be more quickly and easily raised with briquet fuel than with run-of-mine coal.[b]

10. Higher rates of combustion are possible with briquets than with run-of-mine coal.[c]

11. The loss from breakage during transportation of good briquets is less than with run-of-mine coal. This loss should not exceed 5 per cent.

12. The possibility of spontaneous combustion is eliminated if the fuel is stored in the briquetted form, and for this reason fuel in the form of briquets is favored by European countries.

13. The large block-shaped briquets may be piled in regular rows, and occupy less space per ton than the run-of-mine coal. However, the egg-shaped or cylindrical briquets occupy more space than the run-of-mine fuel.

14. Briquets have a higher heating value than the raw fuel from which they are made, by reason of the higher heating values of the binders and the loss of water, especially in the case of lignite, during briquetting.

THE BRIQUETTING OF AMERICAN LIGNITES.

INTRODUCTORY STATEMENT.

The industrial supremacy of the United States is dependent on its fuel resources. A small part of the total fuel supply of the United States has been used, but increase in the cost of mining will lead to a better utilization of the waste products from the mining industry.

Of the five general classes of fuel, namely, anthracite, bituminous coal, subbituminous coal (also called black lignite), lignite (or brown coal), and peat, anthracite and bituminous coals are in most general use to-day in the United States, the subbituminous being used in the West to an increasing extent. Lignite and peat are at present utilized only as local fuels and in a few regions.

In the western and southern parts of the United States there are large deposits of lignite, which, as it comes from the mine, is not suitable for general use as fuel. The high proportion of water or moisture (in some cases as high as 42 per cent) decreases the heat value of the raw lignite; the evaporation of the moisture causes lignite to crumble or slack when exposed to the air for a few days, and to deteriorate greatly during storage or long transportation. Lignite stored in large piles is much more liable to spontaneous combustion than bituminous coal. Lignite is noncoking. As it falls to pieces and readily sifts through the grate, special furnaces are required to burn the raw lignite properly.

---

[a] Goss, W. F. M., Comparative tests of run-of-mine and briquetted coal on locomotives: Bull. 37, Bureau of Mines, 58 pp., 4 pls., 35 figs. (reprint of U. S. Geol. Survey Bull. 363).

[b] Ray, W. T., and Kreisinger, Henry, Tests of run-of-mine and briquetted coal in a locomotive boiler: Bull. 34, Bureau of Mines, 33 pp., 9 figs. (reprint of U. S. Geol. Survey Bull. 412.)

[c] Ray, W. T., and Kreisinger, Henry, Comparative tests of run-of-mine and briquetted coal on the torpedo boat *Biddle:* Bull. 33, Bureau of Mines, 50 pp., 10 figs. (reprint of U. S. Geol. Survey Bull. 33).

Because of its inferiority, lignite has not been used extensively in this country. It has been used in Texas, North Dakota, and other States to some extent as a local household fuel, and is rapidly gaining favor as a gas-producer fuel in the State of Texas. In many localities where lignite is found in abundance, good bituminous coal commands a high price, and for this reason the briquetting of this lignite as a means of improving its heating value and making it available for a household fuel has attracted attention.

German lignite contains a higher percentage of water than American lignite and most of it is so soft that it can be cut with a spade. Many lignite beds in Germany are filled with well-preserved logs and pieces of wood.

EXTENT OF LIGNITE RESOURCES IN UNITED STATES.

The United States Geological Survey has estimated the supplies of coal and lignite in the United States as follows:[a]

Tonnage by grades of coal and accessibility.

[Short tons.]

Kind of coal.	Area, in square miles.	Original supply.		Easily accessible coal still available.
		Amount easily accessible.	Amount accessible with difficulty.	
Anthracite and bituminous	250,531	1,257,766,000,000	505,730,000,000	1,247,672,000,000
Subbituminous	97,636	356,707,000,000	293,450,000,000	356,594,000,000
Lignite	148,609	389,545,000,000	354,045,000,000	389,534,000,000
Total	496,776	2,004,018,000,000	1,153,225,000,000	1,993,800,000,000

A recent estimate[b] made by the United States Geological Survey indicates that the lignite resources are greater than given in the earlier estimate. The later estimate follows.

---

[a] Mineral Resources, U. S., 1907.

[b] In letter to author.

Lignite deposits in the United States, short tons.

State.	Area, in square miles.		Estimated original lignite supply in both easily accessible and accessible with difficulty.
	Containing workable beds.	May contain workable beds.	
Alabama	(a)	6,000	(a)
Arkansas	100	5,900	90,000,000
Louisiana	8,800	(a)	(a)
Mississippi	7,500	(a)	(a)
Montana	33,130		365,474,700,000
North Dakota	29,630	6,350	697,929,400,000
South Dakota	2,160	820	1,020,300,000
Tennessee	1,000	(a)	(a)
Texas	2,000	53,000	23,000,000,000
California	(a)	(a)	(a)
	156,390		1,087,514,400,000

[a] Data insufficient on which to base an estimate.

There are many deposits of lignite in the Western and Southern States, the most important deposits being found in Texas, North Dakota, Montana, and California. These deposits vary in thickness from a few inches up to 80 feet.

PRODUCTION AND VALUE OF LIGNITE IN UNITED STATES.

The following table gives the production and value of lignite mined in the United States in 1910:[a]

Production and value of lignite in the United States in 1910.

State.	Production.	Average price per ton at mine.
	Tons.	
California	11,164	$1.64
North Dakota	595,139	1.49
Oregon	67,533	3.48
Texas	881,232	.87

BRIQUETTING OF LIGNITE IN THE PAST.

Germany and other European countries have been briquetting lignite successfully for 30 years. The main causes why this industry has not been developed in this country are: The low price of high-class American fuels compared with the price of similar fuels in foreign countries, and the small demand for fuel in the western part of the United States where the larger deposits of lignite are found.

A series of investigations was made with the German machine by the Bureau of Mines without the use of any artificial binder. Those lignites that were not made into good briquets in this series of experiments may possibly produce excellent briquets in a machine adapted to working with artificial binders. Preliminary tests with a hand press indicate excellent possibilities in the use of binders in making lignite briquets.

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[a] Compiled from data in "Production of coal in 1910," from Mineral Resources U. S. for 1910, by E. W. Parker, U. S. Geol. Survey.

GERMAN BRIQUETTING PRESS.

The German press, mentioned above, is typical of those used in Germany for briquetting lignite without binders. It is of the open-mold type, and pressure is developed by forcing the lignite through a gradually decreasing opening or tube 3 feet long. This press gives a working pressure of 14,000 to 28,000 pounds per square inch. The capacity of the press is about 3.8 tons per hour, but varies with different lignites according to the ease with which they can be briquetted. The speed varies from 60 to 120 revolutions per minute, the latter figure being the rated speed of the machine when working on German lignites.

RESULTS OF LIGNITE-BRIQUETTING TESTS.

All lignite was shipped from the mines to the plant in box cars to eliminate weathering while in transit. The lignite was stored in covered bins and for each test 3 or 4 tons was prepared for pressing by being crushed, dried, and cooled.

As a result of the tests conducted by the Bureau of Mines, using the German method without binder, it was found that briquets could be made of lignite from the following localities:

Texas.—Lytle, Medina County. Satisfactory briquets made, but lignite difficult to briquet.

North Dakota.—Scranton, Bowman County. Satisfactory briquets made. Lehigh, Stark County. Difficult to briquet, but some fair briquets made.

California.—Ione, Amador County. Excellent briquets easily made.

Lignites from the following localities were not briquetted on the German press:

Texas.—Rockdale; sample insufficient. Calvert; no satisfactory briquets made.

North Dakota.—Vanderwalker; no satisfactory briquets made.

After these tests, tests were made with the hydraulic hand press, various binders being used. The results indicate that certain Texas and North Dakota lignites can be made into satisfactory briquets with the percentage of binder given in the following table as the minimum required.

Minimum percentage of certain kinds of binder required with certain lignites.

Sample from—	Binder.	
	Amount.	Kind.
	Per cent.	
Vanderwalker, N. Dak	8	Water-gas pitch.
Do	3	Flour.[a]
Do	8	Cell pitch.[a]
Calvert, Tex	6	Water-gas pitch.
Do	3	Flour.[a]
Do	8	Cell pitch.[a]

[a] Briquets were not waterproof.

INCREASE OF HEATING VALUE.

The following table shows how the heating value of lignite is increased by the removal of moisture during briquetting:

Improvement of heating value of lignite by briquetting.

Source of sample.	Field designation.	Moisture.			Heating value per pound.		
		In raw lignite.	In briquets.	Removed.	Raw lignite.	Briquets.	Increase.
		Per cent.	*Per cent.*	*Per cent.*	*B. t. u.*	*B. t. u.*	*Per cent.*
Texas	Pittsburgh No. 11.	33.0	9.0	24.0	6,840	9,336	36.5
North Dakota	Pittsburgh No. 8.	40.0	12.0	28.0	6,241	9,354	50.0
Do	Pittsburgh No. 13.	42.0	10.0	32.0	6,079	9,355	54.0
California	Pittsburgh No. 14.	40.0	10.0	30.0	6,080	9,264	52.4

Excessive moisture in fuel not only causes a waste of useful heat during combustion, but also is a source of expense to the consumer, who pays freight charges on useless water. In the case of one of the North Dakota lignites the removal of 32 per cent of moisture during briquetting reduces decidedly the cost of supplying a consumer with a given number of heat units. If the briquets possessed no other advantage over raw lignite than their higher heating value, they would be worth 50 per cent more than the raw fuel. The table shows that the average heating value of the different lots of briquets was about 9,300 British thermal units in each case, although the heating values of the raw fuel varied considerably.

RESISTANCE TO WEATHERING.

The results of the weathering tests indicated that the lignite briquets resist weathering much better than the raw fuel. Some briquet samples after exposure to autumn and winter weather for four months were in nearly as good condition as at first. Samples stored under cover did not show any signs of deterioration after six months, although the raw lignite stored under the same conditions disintegrated in two months.

RESISTANCE TO HANDLING.

The briquets bear handling better than the raw lignite. Their superiority is, of course, more striking after the lignite and the briquets made from it have been stored for several weeks.

EFFICIENCY AS FUEL.

Preliminary results of producer-gas and steaming tests indicate that as gas-producer fuel the briquets were 43 per cent more efficient, and as boiler fuel were 14.5 per cent more efficient, than the raw lignite.

WORK OF NORTH DAKOTA EXPERIMENT STATION.

North Dakota recently passed laws requiring all its public schools to use lignite for heating wherever possible. By act of legislature an experimental plant has been established at Hebron as a substation of the mining-engineering department of the University of North Dakota, and the gas-making and briquetting qualities of the lignites of the State are being investigated by Prof. E. J. Babcock. At present there is no commercial briquetting plant in North Dakota, although there have been numerous promotion schemes projected from time to time within the State. Babcock[a] states that none of the various processes that have been hitherto suggested for the treatment of North Dakota lignite has been adapted to the needs of a successful briquetting industry. As a result of his research he believes that North Dakota lignite can not be made of great commercial value except in the immediate vicinity of the mines, unless it can be raised to a higher fuel value. To accomplish this purpose he has developed a method of removing and saving the gas and other by-products and briquetting the residue with a coal-tar pitch and a starchy material as a binder. This residue has a high fuel value, but does not coke, and would therefore be worthless unless briquetted. When briquetted it becomes nearly equal in heating value to the average anthracite. The briquet is strong, stands shipping well, retains its form while burning, and is of such high heating value that the product can be transported to a considerable distance and marketed at a profit.

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[a] In correspondence with the author.

COST OF BRIQUETTING LIGNITE.

The cost of briquetting lignite should be considered under two heads: (1) Cost of briquetting without binder by the German method; and (2) cost of briquetting with binder on low-pressure machines.

COST BY THE GERMAN METHOD.

In Germany 1½ to 2 tons of raw lignite is required to make 1 ton of briquets. Franke[a] gives figures on the cost of briquetting lignite in a German plant having two presses and a capacity of 120 long tons per 24 hours or 3,000 tons per month. The following table was taken from Franke's work, the German weights and costs having been converted into American units for easier comparison:

Cost of briquets without binder in Germany.

Item.		Monthly.	Per ton of briquets.
1. Interest and depreciation:			
(*a*) Interest, 5 per cent on $111,000		$462.00	$0.400
(*b*) Depreciation—			
10 per cent on $66,000, machinery and equipment		550.00	
5 per cent on $45,000, building		188.00	
2. Raw lignite:			
(*a*) Lignite for 1 ton briquets, 68 bushels, at 1.05 cents per bushel			.712
(*b*) Lignite for boiler fuel, for 1 ton briquets, 34 bushels, at 1.05 cents per bushel			.356
Total, 102 bushels, at 1.05 cents, or monthly, 3,000×102×1.05 cents		3,215.00	
3. Labor for 24 hours (2 shifts):			
2 engineers, at 83.3 cents	$1.66		
2 firemen, at 83.3 cents	1.66		
1 ash remover, at 71.4 cents	.71		
3 coal passers, at 83.3 cents	2.50		
8 drier fillers, at 83.3 cents	6.66		
2 pressmen, at 83.3 cents	1.66		
1 machinist, at 83.3 cents	.83		
12 boys for loading and piling, at 53.3 cents	6.40		
31 men, total pay per day	22.08×25	552.00	.231
2 foremen, 1 weighman, at $47.60 per month each		142.80	
4. Oil, waste, and lighting material		176.00	.059
5. Repairs, maintenance, etc		125.00	.042
Total			1.800

The cost of briquetting without binder by the German method will of course vary to some extent with the location of the plant. The fact that lignite is high in moisture makes it imperative that the plant should be at the mine. In the case of a plant for briquetting bituminous or anthracite coals, the plant may be erected to better advantage away from the mines and near the point of consumption of the briquetted fuel.

COST IN THE UNITED STATES.

Considering now the equivalent briquetting cost in the United States, using an imported German machine and the equipment necessary, all imported, there will have to be added to the German cost of $66,000 for a plant a duty of 45 per cent, or $29,700.

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[a] Franke, G., Handbuch der Brikettbereitung, vol. 1, 1910, p. 591.

The cost of a two-press briquetting plant, equipped with German presses and driers, but in which American auxiliary equipment is used, and all housed in a building of steel and concrete walls, should not exceed $100,000. Such a plant would have a capacity of about 100 tons of briquets per day of 20 hours, or 2,500 tons per month of 25 working days. With this equipment the cost of production in America would be as follows:

Cost of briquets without binder in United States.

Item.		Monthly.	Per ton of briquets.
1. Interest and depreciation:			
(*a*) Interest, 5 per cent on $100,000		$417.00	$0.458
(*b*) Depreciation—			
10 per cent on $75,000, machinery and equipment		625.00	
5 per cent on $25,000, buildings		104.00	
2. Raw lignite:			
(*a*) For briquetting 1.5 tons for 1 ton briquets, at $1.50 per ton			2.25
(*b*) Lignite for boiler fuel, 0.5 ton for each ton briquets, at $1.50 per ton			.75
Total, 2 tons, at $1.50, or monthly, 2,500×2×$1.50		7,500.00	
3. Labor for 20 hours (2 shifts):			
2 engineer-pressmen, at $3	$6.00		
2 firemen, at $1.75	3.50		
2 coal unloaders, at $1.75	3.50		
2 briquet loaders, at $1.75	3.50		
2 roustabouts, at $1.75	3.50		
1 machinist, at $3	3.00		
11 men, total pay per day	23.00×25	575.00	.250
1 clerk or weighman, at $50 per month		50.00	
4. Oil, waste, and light		100.00	.04
5. Repairs, maintenance		125.00	.05
Total			3.878

The cost of briquets made in the United States, with raw lignite at $1.50 per ton at the mines, would be about $3.88 per ton. As 2 tons of raw lignite is used, the cost of the raw fuel is 77 per cent of the total cost.

Using the values given on page 8, the price of Texas lignite at the mine being averaged at 87 cents per ton, the cost of briquets would be:

2 tons lignite, at 87 cents	$1.74
Briquetting costs	.88
Total, per ton	2.62

If North Dakota lignite were used, the cost of briquets would be:

2 tons lignite, at $1.49	$2.98
Briquetting costs	.88
Total, per ton	3.86

If California lignite were used, the cost of briquets would be:

2 tons lignite, at $1.64	$3.28
Briquetting costs	.88
Total, per ton	4.16

As the above figures are based on the value of the lignite at the mine, the cost of briquets would be somewhat less if the briquetting were done by the operator of the mines, as the raw material used might include slacked lignite, which would generally be considered valueless.

From a comparison of the cost of briquets made in Germany with the cost of those made in the United States, it will be noticed that the briquetting cost in Germany, exclusive of the raw fuel used, is approximately 73 cents per ton of briquets, and in the United States it is 88 cents per ton. This increased cost in the United States is due to the higher cost of labor and the shorter working hours (10 instead of 12). The cost would be higher still in the United States if it were not for the greater efficiency per man and the use of mechanical handling of materials. It will be noticed also that the cost of the raw lignite needed to produce 1 ton of briquets in Germany is $1.07, whereas in the United States the equivalent quantity costs $3.

MARKET PRICE OF BRIQUETS IN EUROPE.

A consular report of 1907 gave the following figures of the market price of briquets in Europe:

Market price of briquets in Europe.

Location.	Kind of briquet.	Size or shape (inches).	Weight.	Price.	
				Wholesale.	Retail.
Dresden, Saxony	Brown coal			$1.19-$1.178 per 1,000.	$0.15-$0.20 per 100.
	Bituminous	5 by 3 by 5	1.5-1.6 lbs.	$3.68-$8.80 per 1,000.	$0.38-$0.77 per 100.
Basel, Switzerland.	Anthracite				$9.10 per ton.
	Brown coal				$7.50 per ton.
Hamburg, Germany.	Bituminous		About 6 lbs.	$4.87 per ton	
	Saxon brown coal.		About 6¼ lbs.	$4.04 per ton	
Glasgow, Scotland.	Bituminous(?)	6 by 4 by 3½		$3.28-$3.52 per ton.	$4.25-$4.38 per ton.
Roubaix, France	Bituminous	Cubes			$7.33 per ton.
		Large egg			$7.33 per ton.
		Small egg			$7.72 per ton.
Havre, France	do	Large		$5.40 per ton	$7.53 per ton.
		Perforated		$5.60 per ton	$7.91 per ton.
Paris, France	do	Egg			$9.65 per ton.
		Perforated			$10.80 per ton.
		Solid			$9.26 per ton.
Frankfort, Germany.	Anthracite	12 by 8 by 6			$4.60 per ton.
	do	Egg			$5 per ton.
	Brown coal with 5 per cent coal tar and asphalt earth.	7 by 5 by 2	1 lb	$2.90 per ton	$3.25 per ton.
	Bituminous	12 by 8 by 6	About 10 lbs.	$4 per ton	$4.40 per ton.
	Mixture of bituminous coal, brown coal, and tar.			$2.93 per ton	
Stettin, Germany.	Brown coal	6 by 2 by 1	1.3 lbs.	$4.05 per ton	$5.25 per ton.
	Bituminous	6 by 4 by 2½	About 3 lbs.	$4.52 per ton	$5.75 per ton.
Kehl, Germany	Brown coal			$3.85 per ton	
	Bituminous			$4.55 per ton	$5.27 per ton.
Rotterdam, Holland.	Charcoal			$6.83 per ton	
	Bituminous			$5.63 per ton	
	Brown coal			$4.82 per ton	$5.43 per ton.

Nystrom[a] gives the labor cost of briquetting lignite for plants with one press as 45.4 cents per ton; two presses, 40 cents; three presses, 36.4 cents; four presses, 31 cents; five presses, 27.3 cents; and six presses, 22.3 cents per ton. He further states that "As the wages in Canada are higher than in Germany the cost of labor in a plant with one press is assumed at 60 cents per ton." He estimates the depreciation as 5 per cent per year and the maintenance as 3 per cent, and the cost of a complete plant with one press and a yearly capacity of 13,000 tons as $75,000. His estimate of the charges for depreciation and maintenance is 8 per cent of $75,000, or 46 cents per ton. The cost of labor and fixed charges, according to his estimate, is $1.06 per ton.

In a consular report[b] the cost of briquetting lignite in Germany is stated as follows:

Cost of manufacture of lignite briquets.

Description.	United States currency.
From lignite taken from open workings under good conditions, with about 46 per cent water:	
In large briquet factories	$1.14–$1.29
In small briquet factories	1.19– 1.38
From lignite taken from open workings, with more than 46 per cent water (in large factories)	1.38– 1.62
From lignite taken from deep workings, with about 46 per cent water:	
In large briquet factories	1.31– 1.62
In small briquet factories	1.62– 1.74
From lignite taken from deep workings, with more than 46 per cent water (in large factories)	1.66– 1.86

In the case of materials containing 15 to 18 per cent of water, for which a drying process is not necessary, the cost of manufacture is considerably lower. As the cost of labor and fuel is higher in the United States than it is in Germany, the above figures are useful for comparison only.

Schorr[c] gives costs for the German lignite industry as follows:

> The raw brown coal costs 22 to 31 cents per metric ton (2,204 pounds) at the works. The fixed charges, allowing 7 per cent for depreciation and 5 per cent for interest on the total investment, amount to about $1.30 per metric ton of briquets. The wholesale price f. o. b. the works ranges from $16 to $23 per carload of 10 tons. The labor item rarely exceeds 24 cents per metric ton in small (one or two press) installations. All other manufacturing items, exclusive of fuel and fixed charges, are fully covered by from 8 to 11 cents per ton. In view of the relatively small output of these expensive presses, and in view also of the elaborate character of German briquetting works, the fixed charges (depreciation and interest) are high. The largest brown coal company owns 20 briquetting plants with 52 presses. There are a number of other concerns operating from 8 to 42 presses. Only a few factories employ less than 4 machines.

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[a] Nystrom, E., Peat and lignite; their manufacture and uses in Europe Bull. Canada Dept. of Mines, Mines Branch, 1908, p. 147.

[b] Special Consular Report No. 26, 1903, p. 107.

[c] Schorr, Robert, Lignite briquetting in Germany: Eng. and Min. Jour., vol. 85, 1908, pp. 460–461.

ESTIMATED COST OF BRIQUETTING AMERICAN FUELS WITH BINDERS.

The cost of briquetting fuels in the United States, using a binding material, varies according to the kind of binding material used and the locality in which the briquetting is done. For comparison of this method of briquetting lignite with that given in the previous estimate where no binder was used, the following data may be of interest:

Estimated cost of briquetting American fuels when a binder is used.

Item.		Per month.	Per ton briquets.
1. Fixed charges:			
(a) Interest on investment, 6 per cent on $75,000		$375.00	$0.179
(b) Depreciation—			
10 per cent on $50,000, machinery		417.00	
5 per cent on $25,000 (buildings, etc)		104.00	
2. Labor:			
2 engineer-pressmen, at $3	$6.00		
2 firemen, at $2	4.00		
2 binder men, at $2	4.00		
6 laborers, at $1.75	10.50		
12 men, total pay per day	24.50×25	612.50	.133
1 clerk or weigher, at $50		50.00	
3. Oil, waste, and light		50.00	.010
4. Repairs, maintenance, etc		100.00	.020
			.342
5. Binder 6 per cent (300 tons, at $12)		3,600.00	.720
Total briquetting cost			1.062

The above table is based on the following assumption:

Capacity of plant, 200 tons per day of 20 hours or 5,000 tons per month.

Plant operated 2 shifts of 10 hours each per day.

Cost of plant:

Machinery (American type)	$50,000.00
Building and tracks	25,000.00
Total	75,000.00
Cost of binder, per ton	12.00

Cost of fuel used for power to be included in cost of raw fuel.

The cost of briquetting lignite if a binder be used would, from the above estimate, be approximately as follows:

Cost of lignite briquets with binder.

Locality.	Value of raw fuel per ton.	Tons of raw lignite per ton briquets.[a]	Total cost of raw fuel.	Briquetting cost.	Cost of briquets per ton at plant.
Texas	$0.87	2	$1.74	$1.06	$2.80
North Dakota	1.49	2	2.98	1.06	4.04
California	1.64	2	3.28	1.06	4.34

[a] Including fuel used for furnishing power as well as that used for making briquets.

The cost of briquetting bituminous, anthracite, or subbituminous coals would differ from the above estimate for lignite only in the cost of binder required and the cost of the raw fuel. In the above estimate the briquetting cost, exclusive of binder, was $0.342. If to this figure be added the cost of binder and the cost of fuel, a fair estimate of the cost of briquetting any of the three fuels will be obtained. The allowance to be made for fuel for power and drying will vary from 0.25 ton for anthracite, which is low in moisture and does not require drying, to 0.5 ton for subbituminous coal, which has considerable moisture (as high as 20 per cent).

The average briquetting cost at eight plants in the United States making briquets from anthracite dust or bituminous slack, including the cost of binder but not the fuel briquetted, was $1.454.

Investigations have shown that certain classes of lignites can be briquetted without binder. They are superior to the raw fuel from which they were made, although not equal to bituminous and anthracite coals. Lignite briquets without binder do not hold together in the fire as well as those made with a binder, nor do they resist the effects of moisture as well. Briquets made without binder supply much of the household fuel in Germany. A plant making lignite into briquets without binder is obviously not dependent on a supply of binding material, which is an important consideration for a plant located in an out-of-the-way district. Briquets resist weathering much better than the raw lignite, have a higher heating value, are uniform in size, permit regular firing, and can be stored without serious deterioration. All lignites are not suitable for briquetting without binder and therefore those requiring a binder to agglomerate them are not considered in the above comparison.

It will require further investigation to determine whether Texas lignite can be briquetted commercially without binder. The results so far obtained indicate that binder will be required. North Dakota and California lignites, on the other hand, possess excellent briquetting qualities and probably can be briquetted without binder if a market be developed for this type of briquet. They can probably be made into better briquets by the addition of a binder that will make them stronger and more resistant to weathering.

With the present price of fuel in North Dakota, lignite briquets should there be made to compete with other fuels, but it is doubtful whether the same may be said of the Texas and California fields, where fuel oil and high-grade coal are available.

CHARACTERISTICS OF BRIQUETS.

COHERENCE.

Briquets should possess sufficient coherence to withstand handling and transportation. In a commercial plant briquets must withstand: (1) A drop from the machine to some form of conveyor; (2) the jar received while they are on the conveyor; and (3) a drop from the conveyor to the pile of briquets already in the storage bins or cars. Fresh briquets are hot and soft and are much more easily broken than after cooling and air drying. Most modern plants are arranged so that the fresh briquets do not drop very far from the press to the conveyor belt, and in order to cool them quickly an open-mesh metal conveyor belt has been found most satisfactory, as it permits air to reach all sides of the briquets. The openings in the belt tend to prevent the briquets from rolling as on smooth rubber or leather belting. Scraper, screw, or bucket types of conveyors are not satisfactory for handling fresh briquets, as they break the briquets and do not allow air to come in contact with them. The drop from the end of the conveyor to the storage pile is lessened by the use of chutes.

After cooling and hardening the briquets should be sufficiently strong to stand whatever transportation is necessary to deliver them to the point of consumption with a dust and breakage loss not exceeding 5 per cent. The French use a tumbler test, similar to that described on pages 103 and 104, to determine the cohesive strength of briquets. The details of the test are as follows: [a]

One hundred briquets, each weighing 1.1 pounds (one-half kilogram), are placed in a cylinder 36.22 inches in diameter and 39.37 inches in length. The cylinder is divided into three compartments by diametrical partitions and revolves at a speed of 25 revolutions per minute. After having been charged, the cylinder is revolved for two minutes. The contents are then sifted upon a screen perforated with holes 1.12 inches square. The part that does not pass through this screen indicates the degree of cohesive force, which, in the case of the French Admiralty tests, should reach 52 per cent, or if the fuel be intended for torpedo-boat use, 58 per cent.

Briquets of any desired degree of coherence may be made by varying the proportion of binding material and the pressure. An increase of either the binder or the pressure increases the cost of manufacture. Experiments made by Wéry, of Paris,[a] with a Biétrix machine may be taken as illustrative; the results are given below:

Effect on coherence of varying pressure and amount of binder.

Pressure in kilograms per square centimeter.	Pressure in pounds per square inch.	Pitch used.	Cohesion obtained.
		Per cent.	*Per cent.*
130	1,844	6	25
190	2,695	6	46
270	3,831	6	61
130	1,844	7	52
190	2,695	7	70
250	3,547	7	74

[a] Briquets as fuel: Special Consular Report No. 26, 1903, p. 54.

HARDNESS AND TOUGHNESS.

The briquet should be hard, but not brittle. It is usually advantageous, therefore, to make the briquet of the minimum hardness that will suffice for the purpose in view. A briquet can be made harder by using a binder with a higher softening (melting) point. A larger percentage of the more brittle pitch is usually required.

The requirement of the French Admiralty is that the briquet should not soften at 60° C. (140° F.). Ordinarily it is sufficient that the briquet shall not soften on the hottest day.

DENSITY.

It is sometimes specified that the briquet should have a density of not less than 1.19. Perhaps a better standard would require the briquet to about equal in density the lump coal from which the slack is derived, this ranging from 1.1 to 1.4. The density is increased by pressure.

SIZE AND SHAPE.

The convenience of a briquet for a given purpose, and hence the extent of its use, will depend largely on its size and shape. Heavy rectangular blocks allow a large output for the investment and are consequently cheaper to manufacture, and more convenient to store. The French naval estimates show that 10 per cent more (by weight) of briquets can be stored in a given space than of lump coal, and the British Admiralty reports show a gain of as high as 20 per cent. The large rectangular briquets have the disadvantage of large smooth surfaces and are usually broken when fed into furnaces. To facilitate the breaking they are pressed with grooves or perforations. This gives better air circulation but decreases the output and the compactness of storage.

Prismatic briquets with rounded edges are the most popular abroad. Either these or ovoid shapes weighing less than 2 pounds are preferred for domestic use. The rounded edges cause much less dust and breakage on handling and insure good circulation of air and thorough combustion, but the briquets do not pack closely when stored and are somewhat harder to ignite.

WEATHERING.

The briquet should stand long exposure to the weather with little deterioration. A dense briquet will stand the weather better than a porous one. Briquets are liable to crack in the process of manufacture if they lack the proper proportion of binder, have been improperly mixed, are pressed too wet, or are insufficiently pressed. If the coal be finely ground, the briquets assume a more dense and polished surface, and are therefore more resistant to the weather, Cracks allow the entrance of moisture and cause a rapid deterioration of the briquets on exposure to the weather. Lignite briquets do not stand long exposure to the weather as successfully as other briquets.

The binder used must be insoluble in water. The great obstacle to the successful use of starch, molasses, and sulphite-liquor residues as binders is their solubility, the cost of rendering the briquets waterproof being usually prohibitive. It is possible that in certain dry parts of the West the waterproofing of the briquets could be dispensed with altogether during the dry season, and to a considerable extent during the rainy season if the briquets were kept under cover. With pitches, tars, etc., a slightly increased percentage of binder is necessary in briquets that are to stand long exposure to the weather.

ABSORPTION.

The briquets should not absorb more than about 3 per cent of moisture. The proportion of moisture absorbed is increased when either the original fuel or the briquet is porous, or when the binder used has a tendency to be hydroscopic.

BURNING QUALITIES.

READINESS OF IGNITION.

The ease with which a briquet will ignite depends largely on the fuel used, but can be regulated to some extent. Large briquets ignite less readily than small ones. Sharp edges are an aid to ignition, but this advantage is not so great as to overcome the general preference for the prismatic and egg-shaped briquets. Briquets made from fine slack ignite less readily than those from coarser slack. A dense briquet is also more difficult to ignite. The use of an inorganic substance, such as clay or magnesia, as a binder, or as a constituent of the binder, tends to make the briquets ignite less readily. Increase of inorganic material, that is, ash, in the slack coal used produces the same result.

KIND OF FLAME.

The briquets should burn with a clear, intense flame and with little odor or smoke. The flame produced, as well as the smoke given off, will depend largely on the quality of the coal used and on the completeness of the combustion. The completeness of combustion can be regulated to some extent in the manufacture of briquets by making them of such a shape as to insure a good circulation of air and by the choice of a suitable binder. The smoke does not depend on the total amount of volatile matter in the briquets, but only on that part of the volatile matter that escapes before it is heated to the kindling temperature. The binder should not volatilize before the temperature is sufficiently high to insure complete combustion of the gases formed.

Inorganic binders produce no smoke. Such organic binders as starch, molasses, or sulphite-liquor residues likewise do not volatilize until decomposed, and hence do not smoke, or smoke only little. Pitches, tars, and petroleum residues, when used as binders, volatilize, and will cause smoke and possibly odor if the gases formed are not completely burned. The regular shape of the briquets allows a better regulated air supply and enables a more complete combustion than does lump coal. This reduction of the smoke nuisance is one of the advantages to be derived from briquets.

RETENTION OF SHAPE.

Stability of form is important and depends on the properties of both the coal and the binder. The binder must hold the coal particles together until they are sufficiently softened to cohere. Some bituminous coals cake readily at a low temperature. Semianthracite coals follow next in order, and then anthracite coals. Some of the very hard anthracite coals with only a small proportion of volatile matter have little tendency to cake. Lignites as a class do not cake readily. Those from Oklahoma or New Mexico will cake sufficiently at a rather high temperature to hold together. Some California, Texas, and North Dakota lignites show practically no tendency to soften or cake at any temperature. With such lignites it is extremely difficult to make a briquet that will retain its shape in the fire. Briquets for domestic use can be made from such lignites. These briquets, with the use of a suitable grate, might be used in a variety of manufacturing operations. As a locomotive fuel they would be less suitable.

With a readily caking coal, a binder that volatilizes at a comparatively low temperature may be used. With coals that cake at higher temperatures a less volatile binder must be used. With a lignite that does not cake, the only binder that will enable the briquets to retain their shape until completely consumed is an inorganic binder that does not volatilize, unless sufficient organic binder be added to practically coke the briquets. With such lignites, organic binders that do not volatilize, such as starch, molasses, and sulphite-liquor residues, give results that are fairly satisfactory. The briquets retain their shape until the binder is itself decomposed. As the inorganic binders add ash and as the other nonvolatile binders mentioned are not waterproof, it may be possible to mix a noncaking coal with a sufficient proportion of caking coal. Then with a suitable binder the briquets will retain their coherence in the fire by the softening of the caking coal used.

PERCENTAGE OF ASH.

The proportion of ash left when the briquets are burned is the sum of that contained in the slack and in the binder used. In some foreign countries only 6 per cent of ash is permitted under many of the contracts for briquets. When the ash content of the slack exceeds 6 per cent the briquet may be improved by washing the slack coal before briquetting. This saves freight on an incombustible material, saves binder, and gives in every way a better and more concentrated fuel.

EVAPORATION RESULTS.

The theoretical heating value of a briquet is the sum of the heating units of the coal and of the binder. Organic binders usually equal or exceed in heating value, weight for weight, the slack coal used. They increase the total heat in a given weight of fuel, but owing to the small percentage of binder added, this increase is slight. But the briquets have the advantage over the coal in that they burn with less waste and permit easy regulation and more complete combustion. The evaporation results should at least equal those of the best lump coal from the screenings and dust of which the briquets are made. In many cases the efficiency of the fuel may be increased 10 to 15 per cent by briquetting, when special furnaces are not provided for burning the fuel in its natural condition.

EQUIPMENT OF BRIQUETTING PLANTS.

ST. LOUIS PLANT.

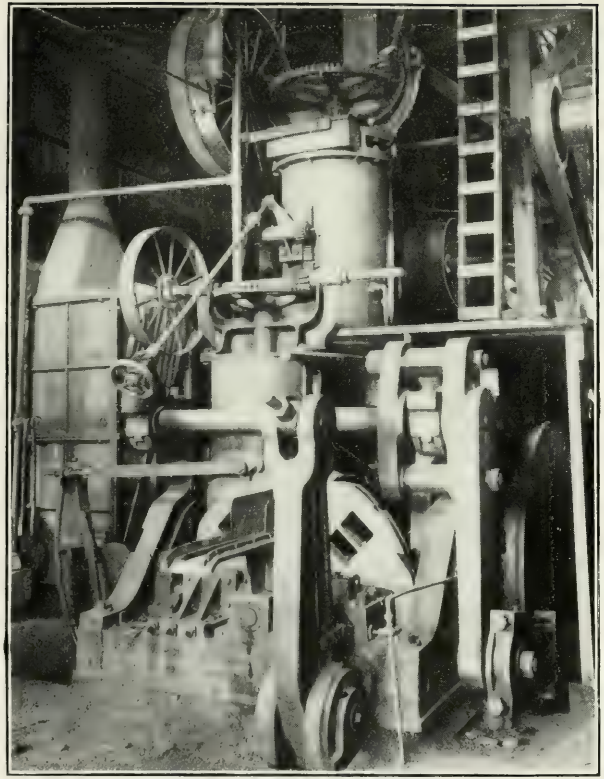
The briquetting plant erected at St. Louis in 1904 had two machines of distinctly different types, one of English and one of American manufacture. The English machine is one of the standard type for briquetting with stiff pitch, and consists of a double-compression, vertical-table press, with closed molds, and accessories. It was operated by a 50-horsepower Westinghouse motor.

The American machine was constructed on Belgian patterns, being what is ordinarily known as the eggette, or Belgian, type of press. It, too, was operated by a 50-horsepower Westinghouse motor.

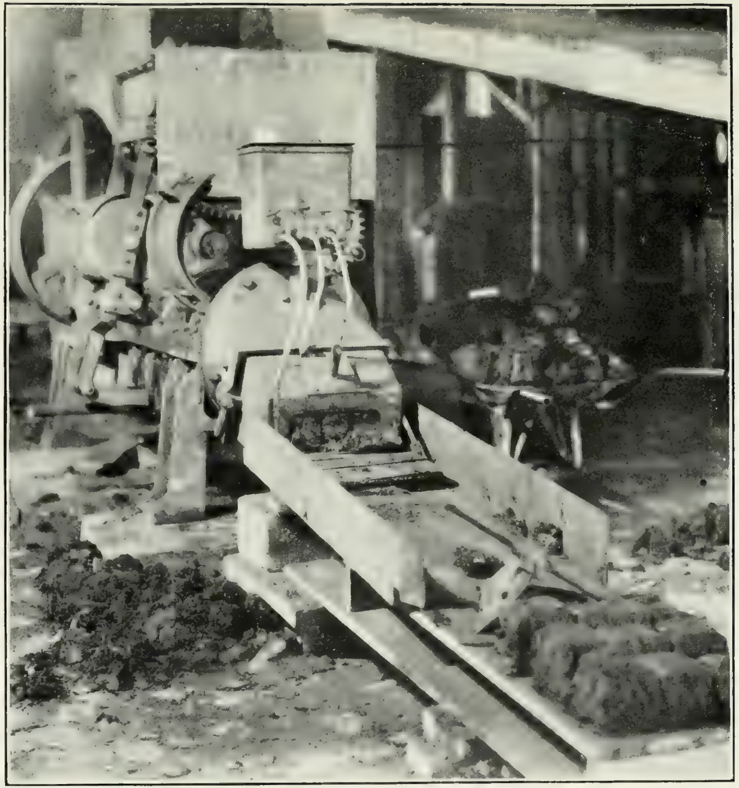
ENGLISH MACHINE.

The English machine as installed at St. Louis is illustrated in Plate I, *A*, which is a general view of the machine.

The coal was delivered to the feeding platform of the English machine by a Robins inclined belt conveyor. It was then shoveled to a coal-feeding worm through a hole in the floor. The pitch that was used as a binder was first reduced to suitable lumps and fed into the pitch cracker, where it was broken to ½-inch size and dropped upon



A. ENGLISH BRIQUETTING MACHINE AS INSTALLED AT ST. LOUIS.



B. SCHLICKEYSEN PEAT MACHINE.

a smaller worm; this in turn delivered it to the coal in the larger worm. The smaller worm was driven by sprockets from the larger one, and the percentage of pitch that was added to the coal could be varied by changing the wheels.

Although this arrangement gave good results when the same coal and binder were used, it was not sufficiently flexible to be adapted to the various coals and binders that were used in the experimental work. For most of the experiments, the crushed coal and cracked binder were weighed and mixed by hand. The mixed coal and binder were then fed to the larger worm through the hole in the floor.

After a slight mixing in the larger worm the material entered an impact disintegrator, in which it was reduced to the desired fineness. The speed of the disintegrator was varied according to the character of the coal. From the disintegrator the material was elevated to a pug mill in which the binder was softened by live steam. As there was no superheater, the range of temperature in which the binder could be softened was limited. Again, live steam is apt to be wet, and was therefore often a detriment to the production of successful briquets. A Foster superheater that was afterwards installed overcame these difficulties almost entirely.

From the pug mill the plastic mixture fell by gravity to the press feed box, from which it was forced by a plunger into brass-lined molds on a vertical revolving table. After a half revolution of the table, the mass in the mold was pressed by a system of compound levers at a pressure of 2 tons per square inch. The pressure, however, could be varied from a few pounds to 4,000 pounds per square inch.

After another quarter revolution, by means of a plunger, the briquets were forced out of the molds to a slide or table set at a height convenient for stacking on trucks. The briquets were taken from the table by hand as soon as they were discharged from the press and stacked on a platform just outside the building. The briquets were rectangular (6 by 5 by 4 inches) except for rounded corners, and weighed on the average 6.8 pounds each. The maximum capacity of this press was 6 tons of briquets per hour.

To obtain a briquet that would more nearly fulfill the requirements of domestic use and of stationary and locomotive boiler practice, the thickness of the briquet was reduced to 2½ inches, the other dimensions remaining the same. By adjusting the machine for this change it was possible to make satisfactory briquets, weighing about 3½ pounds, at the rate of about 4 tons per hour.

This machine was adapted only to those binders that did not become plastic before reaching the pug mill. With inorganic binders or binders made of a number of different materials, it was found necessary to weigh and thoroughly mix the coal with these binders before feeding the materials to the machine. This practice assured a definite percentage of binding material to the quantity of coal taken.

In order to obtain a greater range in the size of the crushed fuel for the briquets, in 1905 a series of pulleys was installed on the driving and driven shafts operating the disintegrator, giving approximately 80, 65, and 50 per cent of its original speed. By these improvements easier and more continuous operation was obtained.

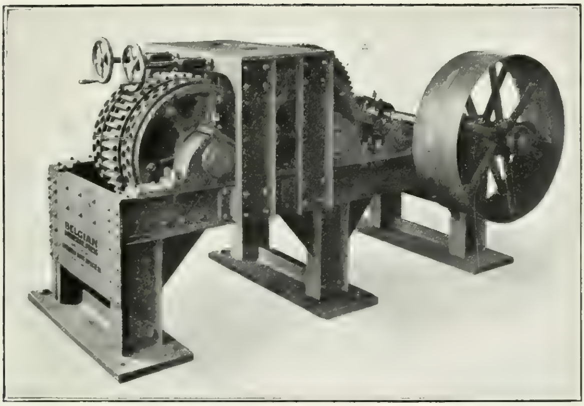
A fire occurred in the latter part of 1905 and destroyed the briquetting plant and all samples of briquets and fuels stored in it. The English machine, however, was not seriously damaged by the fire, but in repairing it considerable care was taken to strengthen certain parts, to provide better lubrication and alignment, and to replace the tight and loose pulleys with friction clutches. The new plant was first operated in May, 1906, and as a result of previous experience it contained some improvements in the methods of crushing, mixing, and conveying the fuel, and of preparing the fuel and binder before briquetting. The new auxiliary equipment for the two machines was not materially different from that originally belonging to the English machine.

The foundation of the Stedman disintegrator was built up level with the floor so as to be more accessible. A 40-ton storage bin was built above the charging floor to allow coal to run by gravity into the hopper scales placed on this floor. A pitch cracker was so placed beside the scales that pitch from it and coal from the scales could pass uniformly to a mixing conveyor directly under the charging floor and be discharged into the disintegrator on the floor below.

AMERICAN MACHINE.

In operating the American plant the coal was received from the Robins conveyor at the level of the second floor in a 3-ton bin. The coal was drawn from the bin to a Fairbanks platform scales, from which it passed into the boot of an elevator, from which it was delivered into a 15½ cubic foot measuring box.

The coal was then dumped into a Buffalo mixer, fitted with steam jackets. The binder was melted in a small steam-jacketed tank that was entirely distinct from the main part of the machine. From the tank it was dipped by hand in the desired proportion and poured into the mixer. After a thorough mixing the mass was dropped into the feed slides of a tangential press. This press consisted of two pairs of narrow-faced rolls (A, Pl. II, *A* and *B*), in the tires of which were ovoid cup-shaped molds. As these rolls revolved, the excess material was squeezed out, the pressure used depending upon the viscosity of the mixture that was being compressed. The 5-ounce eggettes were delivered from under the press to a short rubber belt (B, Pl. II, *B*).



A. AMERICAN BRIQUETTING MACHINE AT ST. LOUIS.

B. AMERICAN BRIQUETTING MACHINE AT WORK.

The capacity of the press was 5 tons per hour, but the output of the mixing device was much too small for operating the press at this capacity. The press had one advantage over the larger English plant, inasmuch as it permitted the testing of mixtures in lots as small as 15 pounds, these small quantities being thrown directly into the feed hopper of the press. In making the small tests and those in which it was desired to use a stiff binder, a 35-gallon kettle was employed for heating the mixture. It was also possible to test on the American machine the mixtures used in the English machine by crushing some of the hot briquets as soon as they were received from the molds and transferring them at once to the feed box of the American machine.

RENFROW NO. 1 MACHINE.

In rebuilding the plant at St. Louis after the fire, an experimental briquetting machine of the plunger type, known as the Renfrow No. 1 machine (Pl. III), was installed. The main difference between it and the English machine was that the Renfrow machine made briquets at each end of the stroke of the plunger. By this design the briquets were kept under compression in the dies twice as long for the same output as they were in machines of the English type. The same length of time for compression being assumed, however, and other conditions being equal, the Renfrow machine had double the output of other plunger-type machines. The period of compression was determined by experience and fixed the speed of the machine. The longer the pressure remained on the warm charge the greater the cohesion and the better the briquet.

Twelve briquets were made on the Renfrow machine at each end of the stroke, or 24 in each revolution. At 12 revolutions per minute the output was 4 tons per hour. The pressure obtainable under ordinary working conditions never exceeded 1,000 pounds per square inch, whereas a pressure of 2,000 to 2,500 pounds per square inch is considered necessary to make satisfactory briquets. For this reason it was found necessary to use a softer pitch and a greater percentage of binder than on the English machine. The fault was somewhat obviated by heating with steam injected directly into the mixture.

A bucket elevator and a divided chute provided with a gate served to convey the fuel from the disintegrator either to the agglomerating cylinder of the English machine or to the storage bin above and directly behind the Renfrow machine. This bin contained an agitator to prevent the fine fuel from packing. The fuel was carried from the bin to the hoppers of the Renfrow machine by belt conveyors. Provision was made for the use of either liquid or hard pitch as a binder for briquets made on the Renfrow machine. During the hot weather considerable difficulty was experienced in conveying the finely divided and thoroughly mixed coal and pitch from the disintegrator to the Renfrow machine. This difficulty was obviated by introducing the melted hard pitch into the coal as it entered the hoppers of the machine, care being taken to keep uniform the temperature and rate of flow of the pitch.

The necessity of maintaining a comparatively large force of laborers about the plant for careful handling of samples, both in the raw and briquetted form, justified the use of more labor in the actual briquetting operations than would be found in a commercial plant. The thorough cleaning of all conveyors, bins, and auxiliary apparatus before briquetting each sample was of as much importance for comparative results as the actual briquetting of the fuel; consequently no attempt was made to develop mechanical means for doing this work.

The briquets made by the Renfrow No. 1 machine were biscuit shaped, being short cylinders about 3 inches in diameter with convex ends. Their extreme length varied from 1½ to 3 inches according to the fuel. The average weight of the briquet made by this machine was 8 ounces. At the close of the tests at St. Louis, in March, 1907, the machine was returned to its owner.

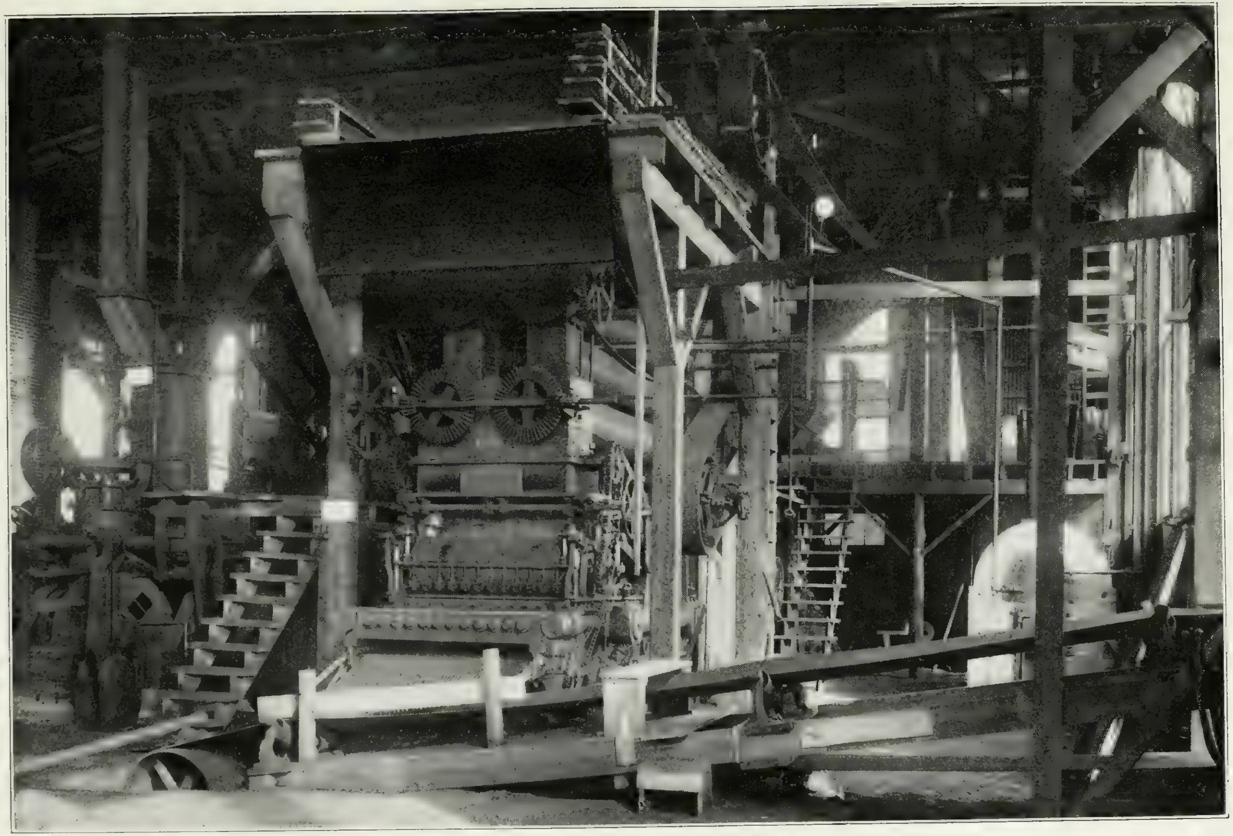
HAND PRESS.

The experimental laboratory contained a small hand press designed for a pressure varying from 0 to 5,000 pounds per square inch. The briquets were cylindrical, one-half inch in diameter, and could be made of any length from one-fourth inch to 1¼ inches. The results obtained on this hand press were verified by the briquets made on the large machines, the formulas for the mixtures having been derived from experiments made with the small press. This press should not be confused with the hydraulic hand press used in experiments at Pittsburgh, described on page 34.

NORFOLK PLANT.

GENERAL DESCRIPTION.

The equipment of the United States Geological Survey briquetting plant at Norfolk comprised three briquetting machines; heating and mixing apparatus; storage bins for the raw fuel; crushers, grinder, and disintegrator for reducing the fuel to the desired fineness; machines for crushing or "cracking" pitch; scales; and the necessary elevators and conveyors. Most of the equipment had been used for varying periods at the St. Louis plant, but of the three machines installed the English machine was the only one that had been used at the St. Louis plant. The machines were (*a*) the English or Johnson press; (*b*) the Renfrow No. 2 machine; and (*c*) a Schlickeysen peat machine.



GENERAL VIEW OF BRIQUETTING MACHINES, ST. LOUIS PLANT.

The general plan of the plant is shown in Plate IV. There were two 25-ton storage bins behind the English machine and one 50-ton bin behind the Renfrow No. 2 machine. The fuel was delivered from the pit at the car track by a bucket elevator and a 16-inch belt conveyor to the storage bins.

Under the coal-storage bins and behind the briquetting presses was the "pitch-mixing platform." On this platform were scales, to which coal could be drawn from the storage bins and weighed. Back of the English machine were other scales to weigh the pitch used as a binder. The Renfrow No. 2 machine had an adjustable mechanical device for keeping the ratio of pitch to coal constant, so that it was not necessary to weigh the pitch used with this machine. A 30-inch Jeffrey belt conveyor 33 feet long (Pls. IV, V, *A*) carried the briquets from the front of the machines to the outside of the building, and a 24-inch Robbins belt conveyor 65 feet long (Pls. IV, V, *A*) carried the briquets from the first conveyor and loaded them into the railroad cars. Plate V, *B*, shows the delivery end of this conveyor.

ENGLISH MACHINE.

The English machine was the same that was erected and used at the St. Louis plant at the time of the Louisiana Purchase Exposition. This machine is described on pages 22 to 24 of this report. As installed at Norfolk, the capacity of this press was 3.8 tons per hour.

The position of the English machine with reference to the Renfrow No. 2 machine and the coal-grinding equipment at the Norfolk plant is shown in Plate IV. Plate VI gives further details of arrangement and equipment.

The scales back of the English machine (Pls. VI, VII, *A*) were placed about 6 inches above the floor to allow room for a square wooden plunger sheathed with sheet iron (D, Pl. VI) to push the weighed fuel into a hole in the floor in front.

Beneath the floor was a horizontal worm conveyor (E, Pl. VI) to carry the fuel and pitch from the scales to a chute leading to the Stedman disintegrator (F, Pl. VI and Pl. VII, *B*). Suspended in this chute was a powerful electromagnet intended to pick up any pieces of iron or steel that might be in the stream of material, and to prevent them from causing damage to the disintegrator or the press. The two sets of hammers in the disintegrator revolved in opposite directions at 790 revolutions per minute. This disintegrator stood on a concrete foundation, and its base was 2 feet above ground level.

In front of the disintegrator a pit 5 feet deep, 3½ feet wide, and 5 feet long, walled in and floored with concrete, was provided for the boot of a bucket elevator (H, Pl. VI). The elevator lifted the ground fuel and pitch to a point above and back of the briquetting machine, whence a covered wooden chute lined with sheet iron

(I, Pl. VI) led to the upper mixing cylinder (J, Pl. VI) of the machine (Q, Pl. VI).

At the base of the upper mixing cylinder steam could be admitted through several openings. Water was supplied at the top of this cylinder when required. Below the mixing cylinder was the feeding cylinder (K, Pl. VI) of the briquetting press.

To conduct a briquetting test on the English machine, coal was drawn from one of the storage bins, weighed, and mixed with binder.

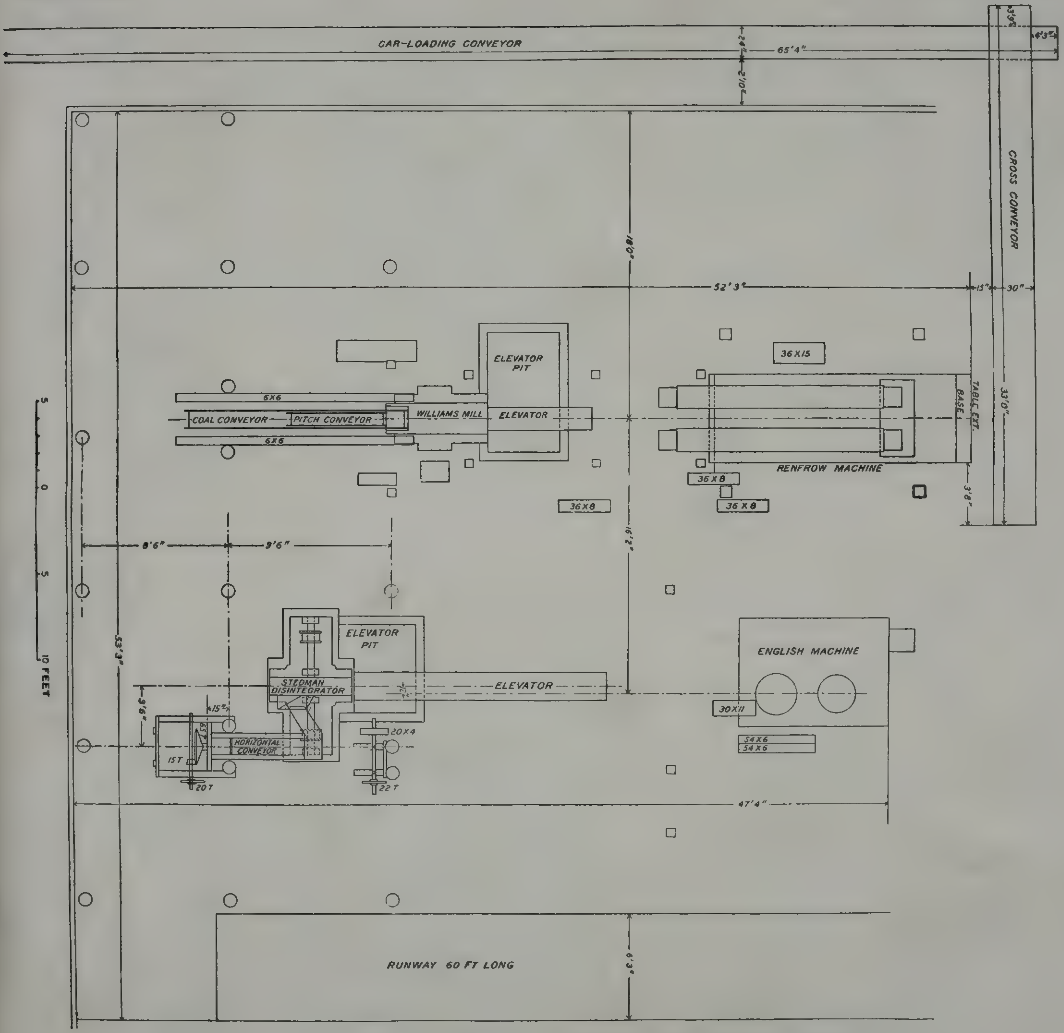
After the fuel and the binder had been thoroughly mixed and properly heated the mass became more or less plastic, according to its briquetting qualities, and was drawn into the feed box through a door in the lower part of the cylinder. From the feed box the mixture was forced by a plunger into the molds in the vertical revolving table of the press. The plunger speed was 17 strokes per minute, 1 stroke for each revolution. At half a revolution the mass in the mold was pressed by a system of levers from each end, the maximum pressure being about 4,000 pounds per square inch. Two briquets were formed at each stroke, or 34 briquets per minute.

The finished briquets were removed from the machine by hand and either stacked near the machine or placed on the conveyor in front of the Renfrow No. 2 machine and by it loaded directly into a car. They were rectangular, with rounded corners, 6¾ inches long, 4¼ inches wide, and 2½ inches thick. Their average weight was about 3¾ pounds. The maximum capacity of the machine was about 30 tons per 8-hour day.

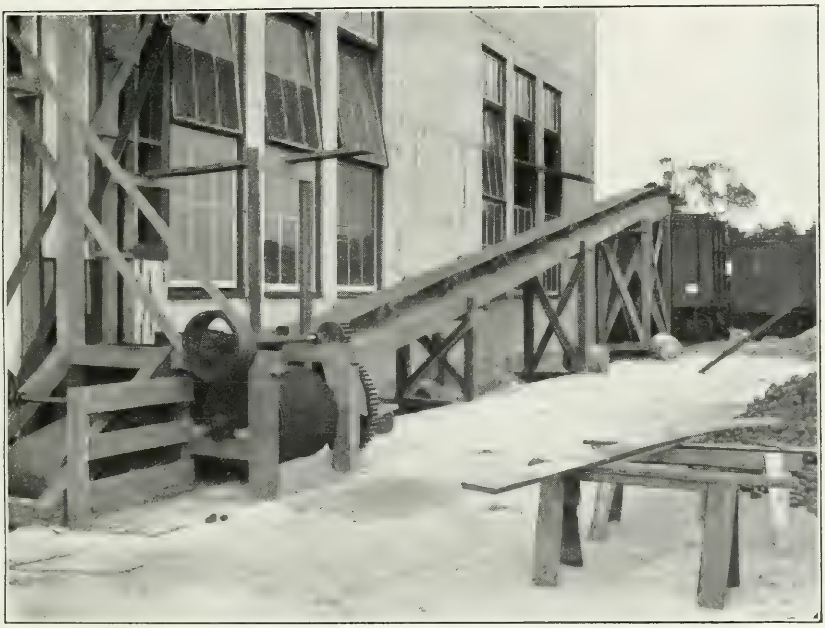
RENFROW NO. 2 MACHINE.

The Renfrow No. 2 machine installed at Norfolk was an improvement over the No. 1 machine, as defects of the first machine, brought out by the tests, were corrected. The new machine had a stronger frame to permit the use of heavier pressure. The working parts not subjected to pressure were of bronze to prevent corrosion; the dies, cams, and rollers were of tool steel. Provision was made in the design of the housing for the removal of any working part without dismantling the machine, and the arrangement of the die plunger and the length of spring behind the plunger were such as to reduce to a minimum the chance of a double charge entering the press and to prevent damage to the machine if one did enter.

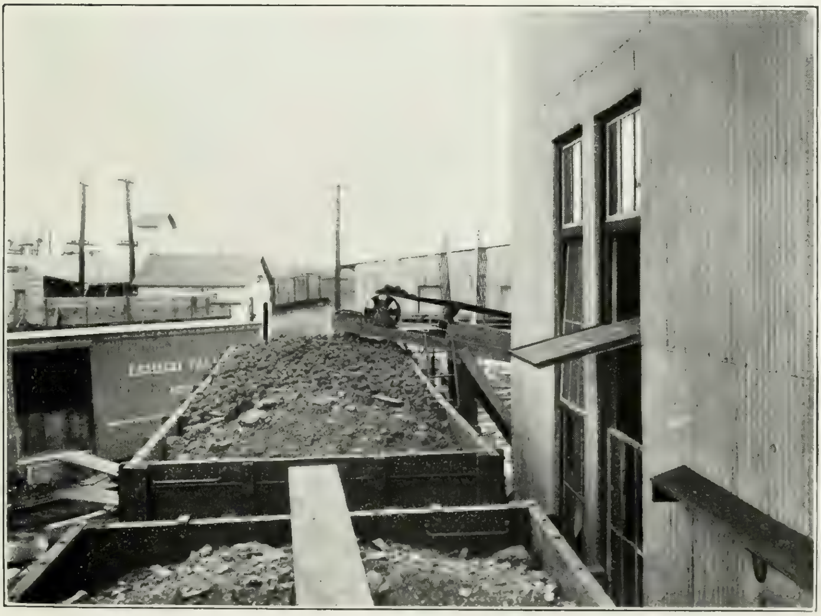
The Renfrow No. 2 briquets were cylindrical, with convex ends. They measured 3¼ by 1½ inches and weighed 11 ounces. This machine was a closed-mold double-acting plunger machine, forming 12 briquets at the end of each stroke, or 24 at each revolution. Running at 9 revolutions, or 18 strokes per minute, the capacity of the machine was about 8.9 tons per hour.



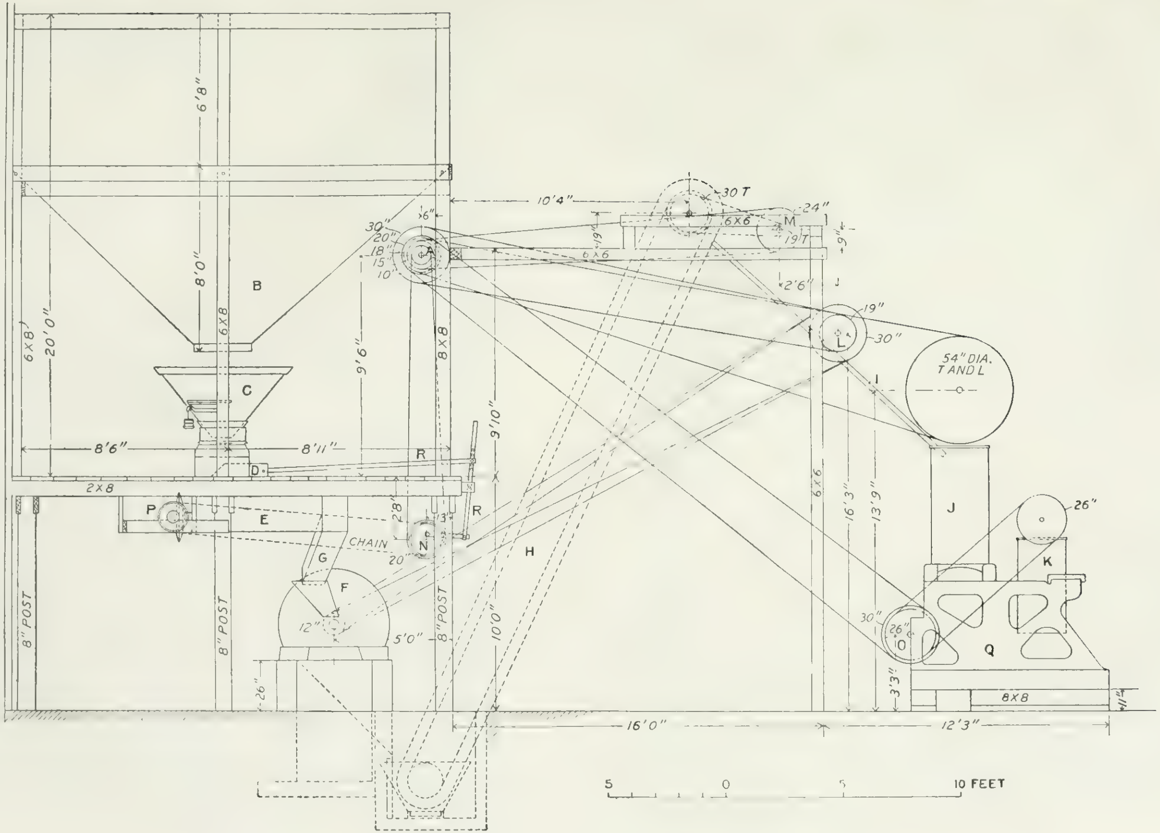
PLAN OF BRIQUET EQUIPMENT AT NORFOLK FUEL-TESTING PLANT.



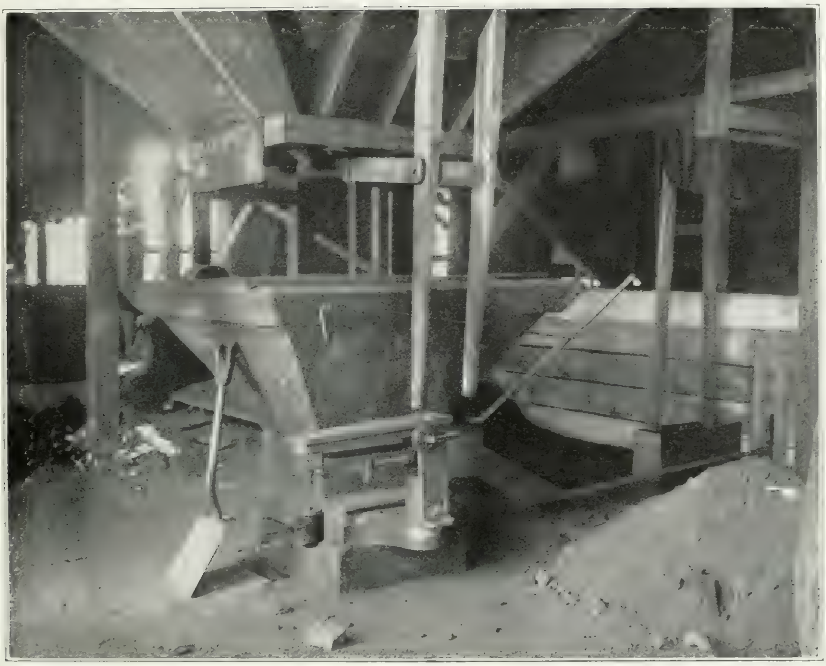
A. PLANT END OF CAR-LOADING CONVEYOR, SHOWING END OF CROSS CONVEYOR.



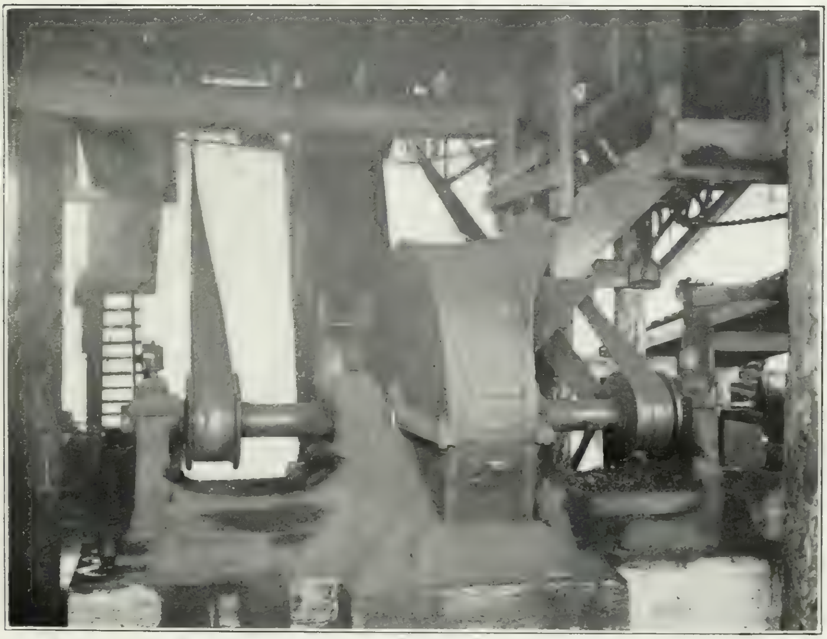
B. CAR-LOADING CONVEYOR FILLING CAR WITH BRIQUETS.



ELEVATION OF ENGLISH BRIQUETTING MACHINE.



A. HOPPER AND SCALES BACK OF ENGLISH MACHINE.



B. STEDMAN DISINTEGRATOR.

The location of the storage bin, mixing platform, coal crusher, conveyor, the pulleys and belting that drove the press, and the various accessories are shown in Plate VIII; the location of the machine with reference to the English machine is shown in Plate IV.

The Renfrow No. 2 machine equipment included a 50-ton bin (H, Pl. VIII), situated above and behind it; hopper scales (I, Pl. VIII and Pl. IX, *A*); a pitch cracker (L, Pl. VIII, and Pl. IX, *A*); a hopper with adjustable slides in the bottom at the coal scales (J, Pl. VIII); an apron conveyor for the cracked pitch (M, Pl. VIII); a Williams mill (K, Pl. VIII); and a bucket elevator (N, Pl. VIII). The machine itself included steam-jacketed cylinders (PPP, Pl. VIII) for heating and mixing the fuel and binder; worm conveyors for forcing the mixture through the cylinders; a feed box (T, Pl. VIII); a die filler (U, Pl. VIII); a conveyor for bringing the briquets to the front of the machine, and a double-acting press (R, Pl. VIII).

For a test on the Renfrow machine sufficient fuel to fill the hopper on the scales (Pl. IX, *A*) was drawn from the storage bin and weighed; the slide at the bottom of the scales was opened, and the fuel passed through a hole in the floor of the pitch platform into a hopper over the apron conveyor. A sliding door on the side of the hopper could be raised or lowered to vary the thickness of the layer of fuel on the conveyor.

Pitch broken by hand into lumps was fed into the pitch cracker (Pl. IX, *A*). The apron conveyor under the pitch hopper discharged the pitch in an even layer upon the fuel lying on the fuel conveyor below. Plate IX, *B*, shows the arrangement of these conveyors. The fuel and pitch were ground in the Williams mill and elevated to the hopper above the Renfrow No. 2 machine. The screw conveyors moved the material flowing from the hopper through the three pairs of horizontal steam-jacketed drums, in which the fuel and binder were suitably heated and thoroughly mixed. The briquet mixture then passed to the press box, whence plungers forced it into die fillers. Then the briquets were formed under an average pressure of 1,000 pounds per square inch. The briquets were discharged from the molds on the return stroke. The capacity of the Renfrow No. 2 machine was 71 tons per 8-hour day when making 18 strokes per minute.

SCHLICKEYSEN PEAT MACHINE.

The Schlickeysen peat machine used at the Norfolk plant for experimenting with North Carolina peat was of the auger type. The peat was macerated by a screw or worm and then squeezed through a tapered tube in a continuous stream; briquets of the proper length were cut off by a wire cutter. The general appearance of the machine is shown in Plate I, *B* (p. 22). In addition to the machine itself, the equipment consisted of a scraper conveyor for elevating the peat to the top of the machine and a number of wooden shelves, about 2 by 4 feet and 4 inches high, which were nailed to cleats on edge. The shelves received the briquets direct from the press and could be stored in tiers one above the other to permit drying.

PITTSBURGH PLANT.

GENERAL DESCRIPTION.

At the experiment station of the Bureau of Mines at Pittsburgh a complete lignite-briquetting plant is installed in the main part of the briquetting building. The equipment, which was furnished by the Maschinenfabrik Buckau Actien Gesellschaft, Magdeburg, Germany, is as follows: Tubular drier, sorting sieve, auxiliary crushing rolls, cooler, screw conveyor, large storage hopper, briquetting press directly connected to a steam engine, apparatus for conveying briquets, shafting, hangers, and extra sets of dies. To complete the plant the United States Geological Survey erected a coal elevator, a crushing roll, and the necessary belting and piping, in addition to the building and stacks.

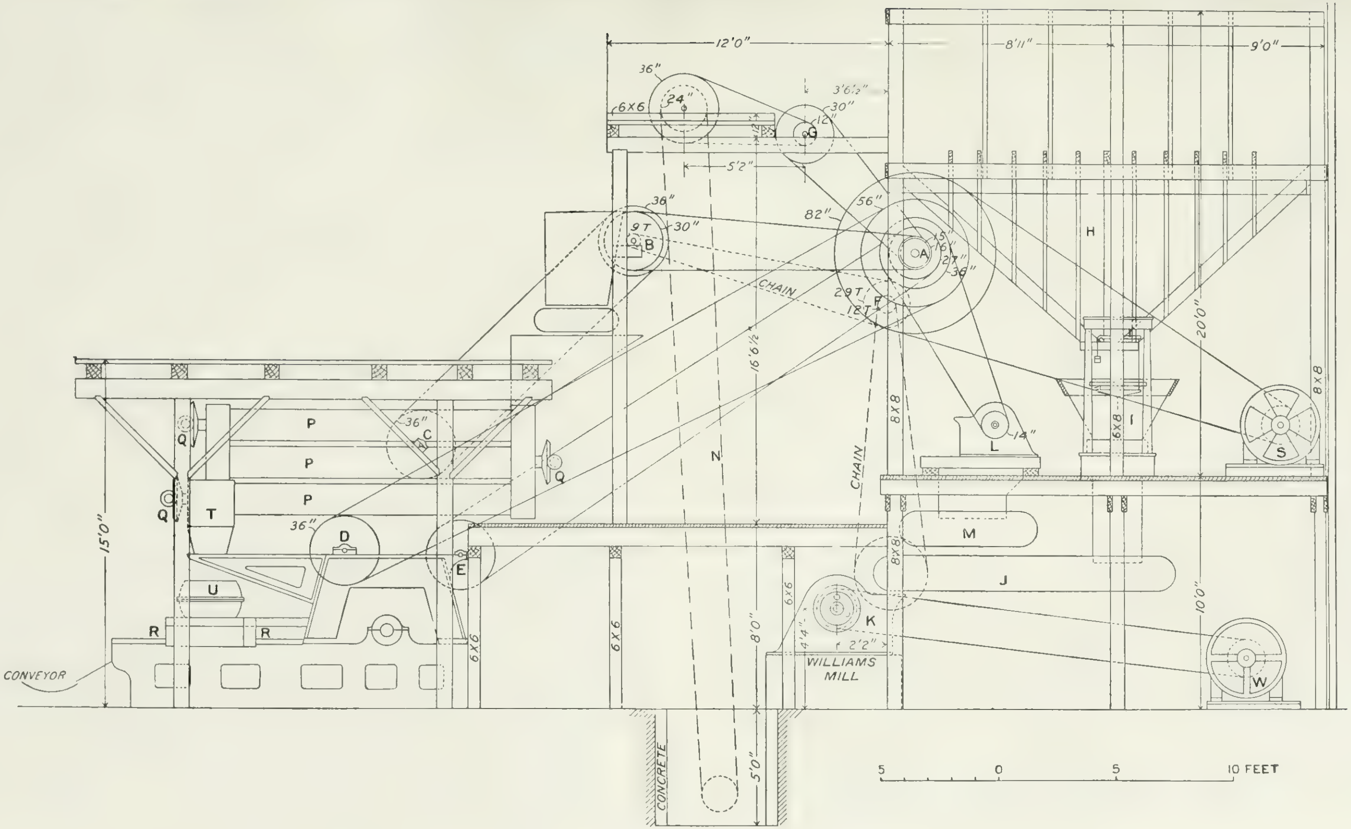
The English machine used at St. Louis and Norfolk for briquetting anthracite and bituminous slack and coke breeze was set up in the building, but no provision has been made for using it to briquet large quantities of fuels. Work at this plant has been concentrated on tests of lignite with the German machine.

Briquetting machines at Pittsburgh and their equipment are housed in a steel-frame building inclosed with curtain walls of reinforced concrete 2 inches thick. The steel work is of heavy construction, for it has to carry not only the machinery but also, on the third floor, a storage room to hold 100 tons of coal or lignite. Plate X illustrates the general appearance of the building.

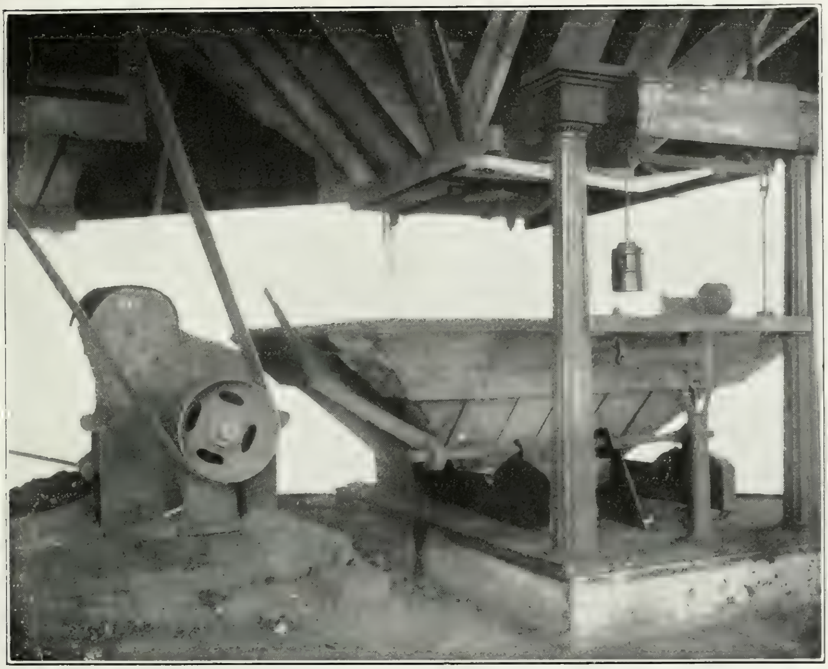
CONVEYOR AND CRUSHER.

Two 60-ton bins for storing the raw lignite were built near the car track at one side of the briquetting building, so that the lignite could be shoveled directly into them from the box cars in which it had been shipped from the mine. A bucket elevator (fig. 1) of the link-belt type carries the raw lignite from the receiving bin to the third floor of the building.

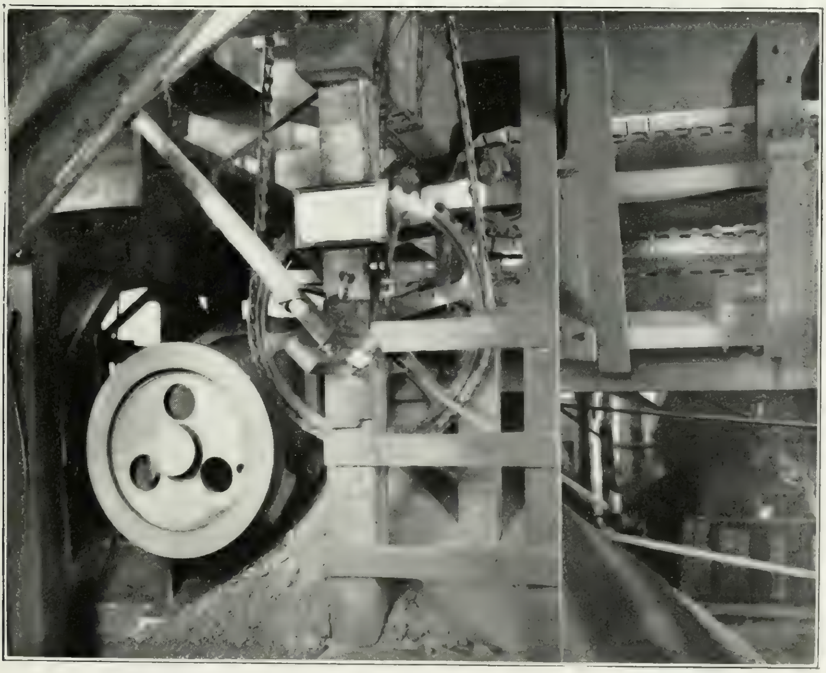
The corrugated single-roll crusher (A, figs. 1 and 2) installed on the third floor was expected to break run-of-mine lignite into pieces three-eighths of an inch in diameter or smaller at one operation. The North Dakota lignite, being tough and woody, was especially hard to crush, and some samples had to be run through the crusher several times. The tests indicated that lignite should be crushed in stages,



ELEVATION OF RENFROW NO. 2 BRIQUETTING MACHINE.



A. PITCH CRACKER, SCALES, AND HOPPER BACK OF RENFROW NO. 2 MACHINE AT NORFOLK.



B. ARRANGEMENT AND DRIVING GEAR OF PITCH AND COAL MIXING CONVEYORS.

BRIQUETTING-PLANT BUILDING AT PITTSBURGH.

first by a toothed roll and then by a smooth or corrugated roll or by a disintegrator. In Germany three sets of crushers are used in lignite-briquetting plants.

DRIER.

The Schulz tubular drier (C, figs. 1 and 2), on the second floor of the building, is similar to an ordinary multitubular boiler, $22\frac{1}{2}$ feet long, $7\frac{1}{2}$ feet in diameter, and contains 195 tubes of $3\frac{3}{4}$ inches inside diameter, evenly spaced around the drum. The material to be dried passes through the tubes, which have a drying surface of 4,310 square feet. A worm gear turns the drier at a speed of 5.2 revolutions per minute.

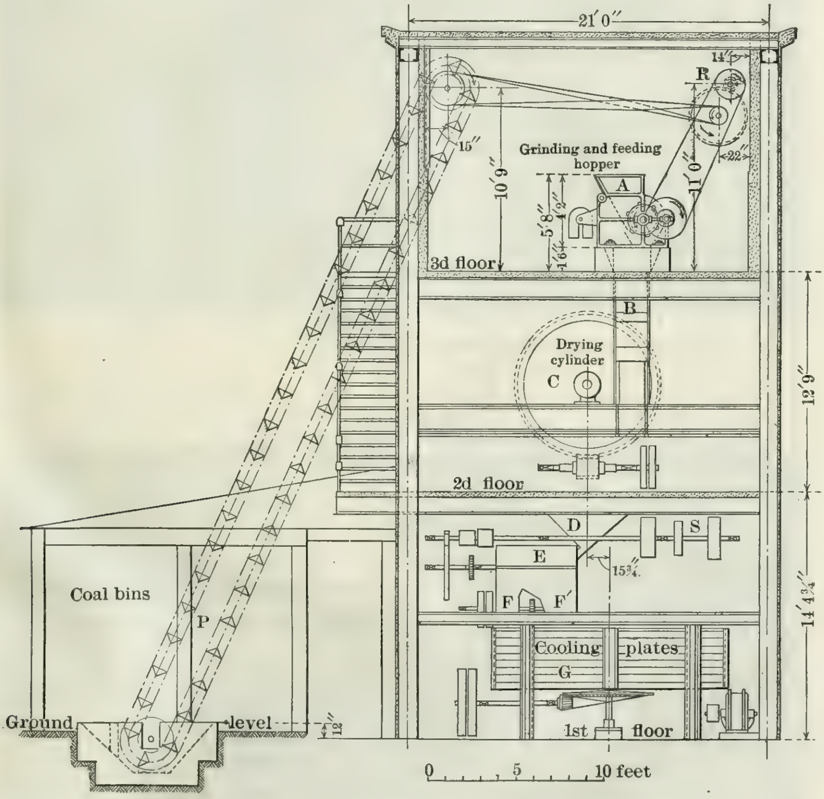


FIGURE 1.—Cross section of lignite-briquetting plant.

A 5-inch pipe carries the exhaust steam from the engine of the briquetting machine to the drier, the steam entering the latter through the upper bearing. During the tests steam pressures of 3 to 30 pounds per square inch are used, according to the degree of dryness desired. Live steam is used when the engine is not running. The ground lignite is fed into the drier tubes by a chute (Pl. XI, *A*) from the roll crusher.

The lower or delivery end of the drier is connected with a revolving screen by a hopper (D, figs. 1 and 2, and Pl. XI, *B*). This screen has openings of two sizes; those in the receiving half are three-sixteenths inch square, and those in the other half are three-eighths inch square. Material larger than three-eighths inch is discharged from the end of the screen through a waste pipe.

The material that passes the $\frac{3}{16}$-inch openings falls through a chute (F′, fig. 1) into the cooler, and the material passing the three-eighths-inch screen falls on a pair of rolls, is crushed to a fine powder, and then goes into the cooler shown at F, figure 1.

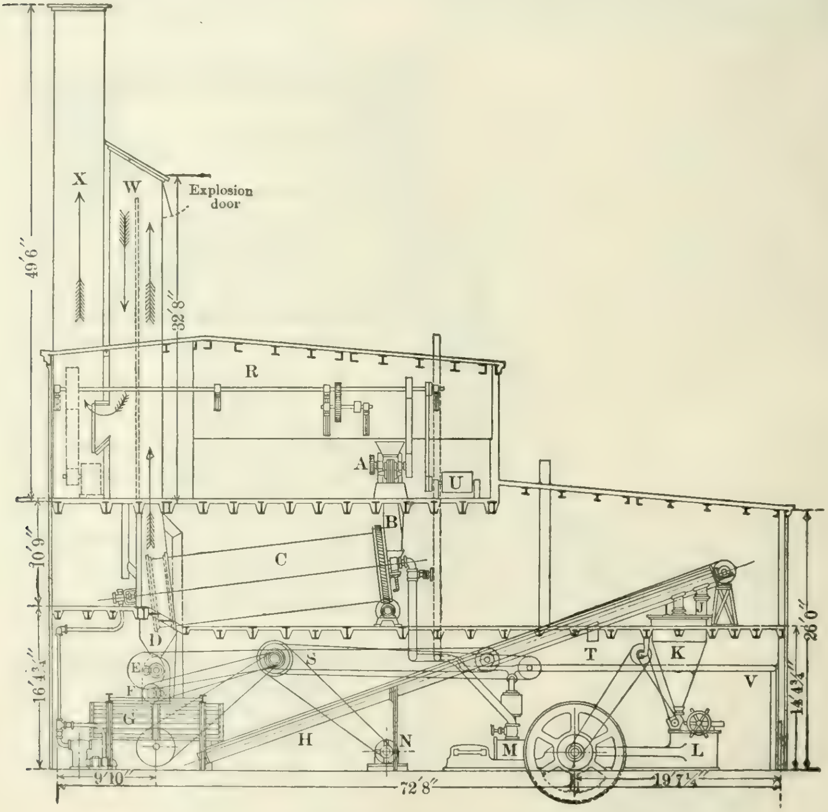
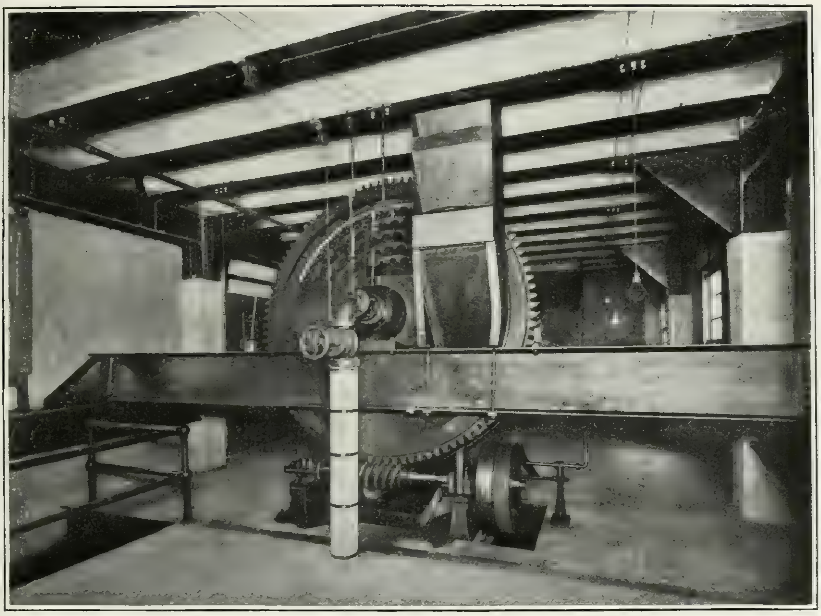


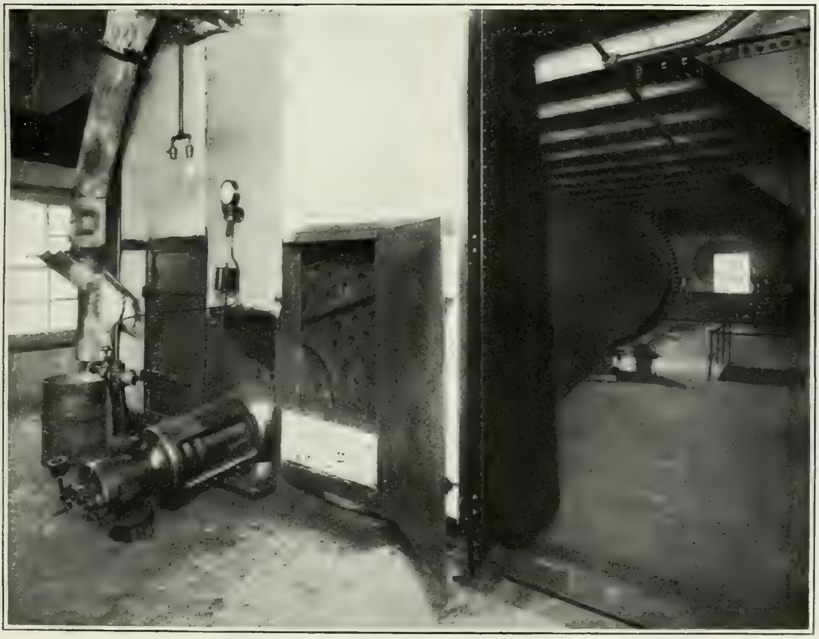
FIGURE 2.—Longitudinal section of lignite-briquetting plant.

COOLER.

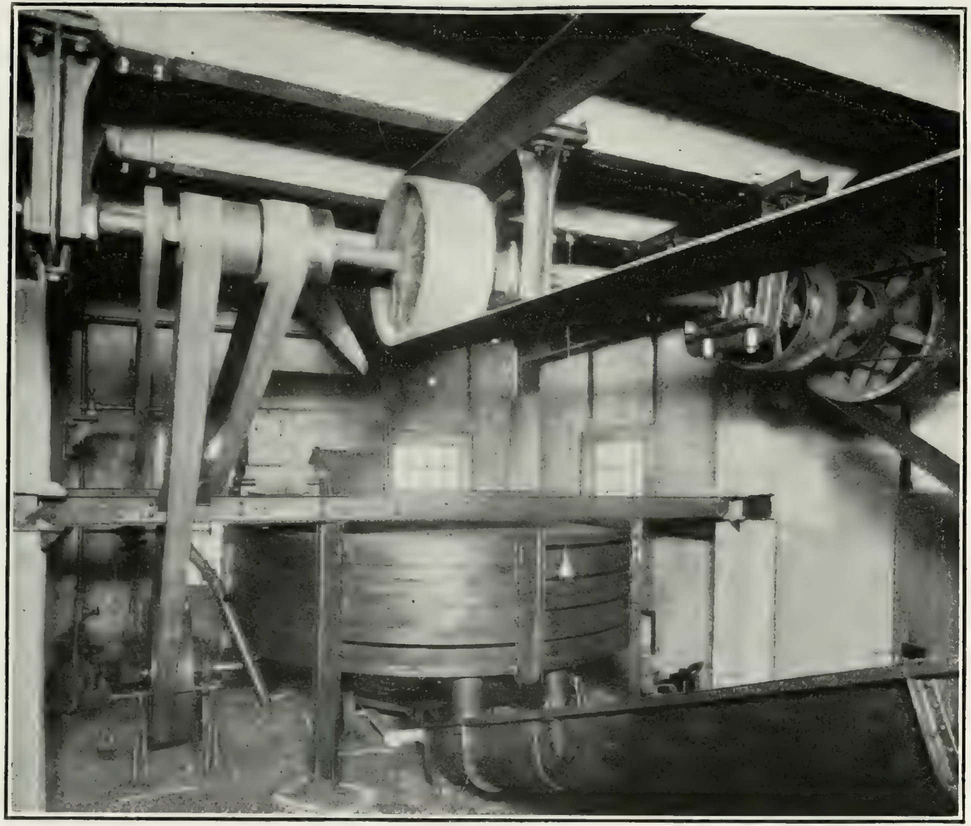
The cooler (G, figs. 1 and 2, and Pl. XII, *A*) has four circular stationary plates 13 feet in diameter, arranged one above the other, with raised edges and closing plates to keep the dust from escaping. Over each plate four radial arms, each carrying several scrapers set at an angle of 45° with the arms, are revolved by a vertical central



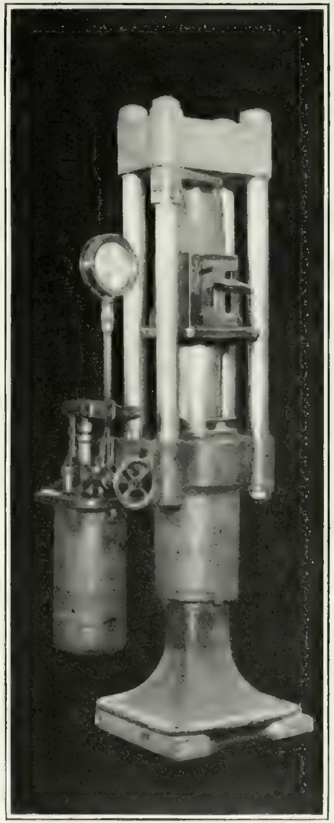
A. RECEIVING END OF SCHULZ DRIER.



B. DELIVERY END OF SCHULZ DRIER.



A. SCREEN, CRUSHING ROLLS COOLER, AND ELEVATOR TO SECOND FLOOR OF BUILDING.



B. LABORATORY HAND PRESS

shaft. The material is scraped from the outer edge of the upper plate toward the center, where it falls through holes to the plate below; another set of scrapers moves it to the outer edge of that plate and another set of holes. Thus it reaches the bottom plate, from which it goes to a worm conveyor (H, fig. 2, and Pl. XII, *A*). This conveyor elevates the cooled material to the second floor, where it falls through chute I (fig. 2) into large hopper K (fig. 2) over the German press L (fig. 2).

DUST STACKS.

The dust and gases from drying lignite may form explosive mixtures with air; hence stacks (W and X, fig. 2) were erected over the delivery end of the drier to carry off the dust and gases, as shown by the arrows in figure 2. An explosion door is placed at the upper end of stack W. Most of the dust settles in the down-coming section of stack W and goes to hopper D through a chute. A spray was put in stack X to wash out any dust that remained in the gases and to condense steam and other vapors. The air current up the stacks tends to increase the capacity of the drier.

GERMAN MACHINE.

The German machine (Pl. XIII) was designed to briquet either peat or lignite that will cohere under pressure because of inherent bituminous matter. Attempts to use a similar press for briquetting materials containing artificial binder will probably result in a stalled machine or a broken stamp.

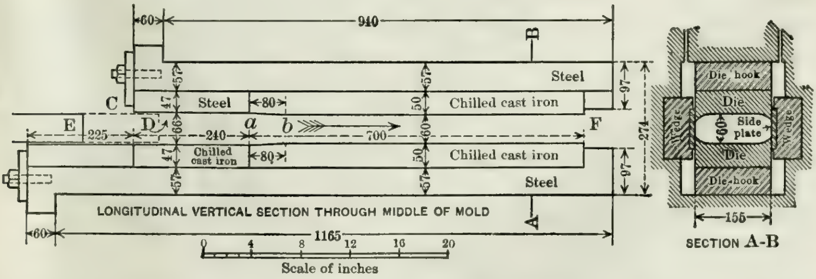


FIGURE 3.—Vertical sections through mold box of lignite-briquetting press; dimensions are in millimeters (25.4 mm.=1 inch).

The machine is of the open-mold type. As the material passes through the mold it is reduced in volume, because the opening in the delivery end of the mold is smaller than the one in the receiving end. This difference in the size of the two openings is shown by the vertical sections through the mold given in figure 3. In the following paragraph the letter references pertain to this figure.

A charge enters the mold at C, is pressed by the stamp E into the end of the mold and is pushed along to D, the end of the travel of the stamp E. The stamp moves back and then presses another charge to D. The first charge is forced along under heavy pressure in the direction of the arrow until it reaches *a;* as it passes from *a* to *b*, in what is called the die angle, it is compressed at top and bottom by the reduction in height of the mold. From *b* the briquet is forced along by the successive charges of material and its sides are hardened and polished. When it leaves the mold at F the briquet is hot, but after it has traveled a few feet in a trough it is ready for storage or loading into cars.

The briquets made by the German press have flat sides and rounded ends. A good idea of their appearance may be obtained by referring to Plate XVI. They measure approximately 6¼ by 2½ by 1 inch and weigh about 1 pound apiece.

ENGLISH MACHINE.

The English machine, shown in Plate XIV, was described on pages 27 to 28. This machine is suited for briquetting any solid fuel with added binder. No provision was made for experiments with this machine during the fiscal year ending June 30, 1909, and its equipment was not completed.

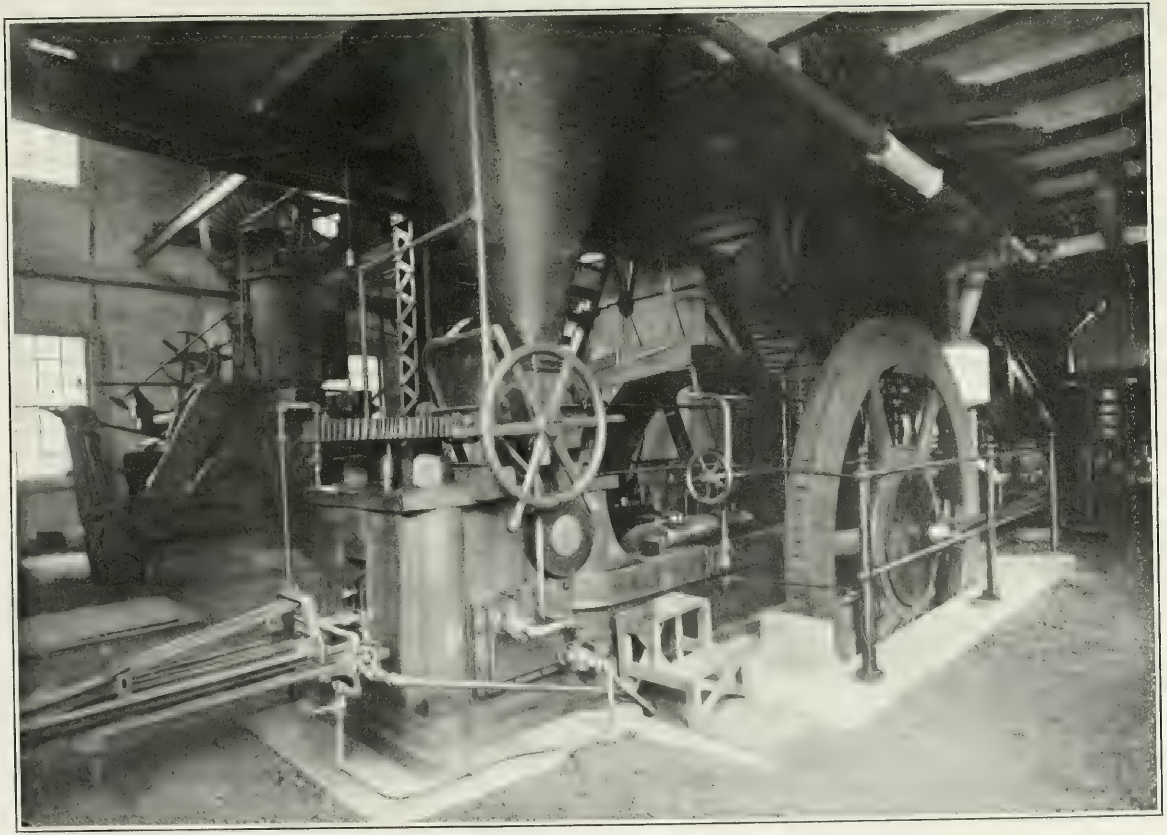
LABORATORY HAND PRESS.

A laboratory hydraulic press (Pl. XII, *B*), operated by hand, is used for preliminary investigations. It contains a mold 3 inches in diameter and 9 inches long, around which is a steam jacket. This press is adapted for tests of briquets with or without binding material and with hot or cold dies. The pressure obtainable with the 3-inch mold is 50 tons, or 14,000 pounds per square inch. By using a smaller mold (2-inch) a pressure of 32,000 pounds per square inch could be obtained. The press has proved very useful and many tests were made with it, but as the tests with the press were preliminary a discussion of only a part of them is included in this report.

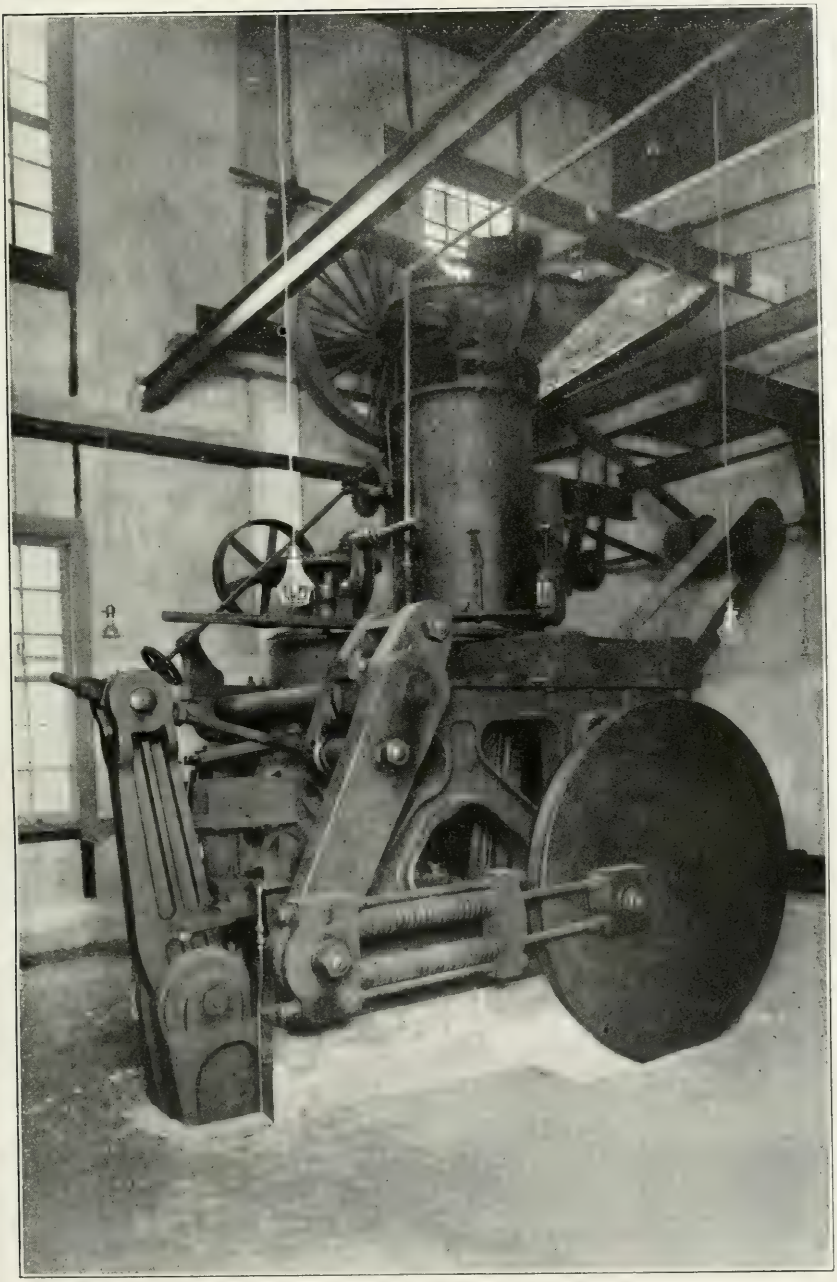
METHOD OF MAKING TESTS ON GERMAN PRESS.

In making a briquetting test about 3 tons of lignite was crushed, dried, and screened by the apparatus previously described for each machine.

In each test the raw material as it was fed into the drier was sampled for chemical analysis and determination of heating value. The dried and cooled material was sampled as it fell into the hopper (K, fig. 2) and its temperature and moisture content were determined. A sample of the briquets was taken for analysis and determination



GERMAN BRIQUETTING MACHINE; ENGLISH MACHINE IN BACKGROUND, AT LEFT.



SIDE VIEW OF ENGLISH MACHINE AT PITTSBURGH.

of heating value. Sizing tests of the raw fuel and the mixture were also made from time to time.

The tests on the German machine described in this bulletin were made without the use of any artificial binder. Those lignites that are not made into good briquets in the German press may, perhaps, be made into excellent briquets in a machine adapted to working with an artificial binder. There is opportunity for further experiments in this direction.

Only small lots of lignite could be tested at a time, because the size of the hopper over the press controlled the quantity of material dried. Only enough material was fed to the drier to fill the hopper. The necessity of drying small lots was unfortunate, as about 6 tons of material could be put through in the time needed to get the apparatus warmed to working temperature, and the use of only about 3 tons of lignite for a test resulted in the first part of each lot being dried more than the last part.

DIE ANGLES USED.

The "die angle," or "angle of dies," is the angle to which one end of the long die blocks is ground to decrease the sectional area of the mold, and thus compress the material passing through. This angle may be seen by referring to figure 3, in which the die angle extends from *a* to *b;* the tangent of the angle may be found with sufficient accuracy by dividing the decrease in vertical height of the mold (*a* minus *b*) by the length of the part ground off. As the angular measure in degrees does not convey such exact information as do the dimensions of the part removed by grinding, the latter are styled the "die angle" in the notes on the tests. In the tests here reported various die angles were used, ranging from $\frac{1}{60}$ to $\frac{8}{68}$, as shown in the following table:

Dimensions of die angles used.

Decrease in vertical height.	Length of die angle.	Ratio or tangent.	Angle of which ratio is tangent.	Decrease in vertical height.	Length of die angle.	Ratio or tangent.	Angle of which ratio is tangent.
Mm.	*Mm.*		° ′	*Mm.*	*Mm.*		° ′
1.0	60	0.016	0 55	5.0	89	0.0562	3 13
1.5	60	.025	1 26	5.5	89	.0618	3 32
3.0	76	.0394	2 15	6.0	89	.0674	3 51
4.0	110	.0364	2 5	7.0	89	.0786	4 30
4.0	89	.0450	2 35	8.0	68	.1176	6 42

PRESSURES USED.

The German briquetting press was built to give a working pressure of 14,000 to 28,000 pounds per square inch, and as the area of the face of a briquet was 15.55 square inches, the total pressure developed by the machine was 217,700 to 435,400 pounds. The pressure actually used in the different tests could not be determined, and could be approximated only when the material stalled the machine, the pressure then being maximum.

LADLEY BRIQUETTING PRESS.

Through the courtesy of the Indianapolis Pressed Fuel Co. the use of their briquetting plant was obtained to carry out some tests of California lignite without binder and of Philippine lignite with binder at a time when the plant of the bureau was not in condition to make tests. It was also desirable to determine whether an American-made machine would give as satisfactory results as foreign-made machines for briquetting American fuel. The Ladley press at the above company's plant is of the rotary-plunger type and has two rows of molds, 54 molds in each row, arranged in the heavy rim of a wheel. The machine exerts a pressure of 5,000 to 6,000 pounds per square inch. The construction of the press is shown by the views in Plate XV.

FUELS TESTED.

At the three experiment stations various fuels from different sections of the United States have been subjected to briquetting tests. The following table indicates the kind of fuels tested, the localities from which the shipments were received, the name of the experiment station at which they were tested for briquetting qualities, and the pages of this bulletin on which a description of the tests made are reported. A few of the coals were used only in tests of binders, as reported in Bulletin 24.[a]

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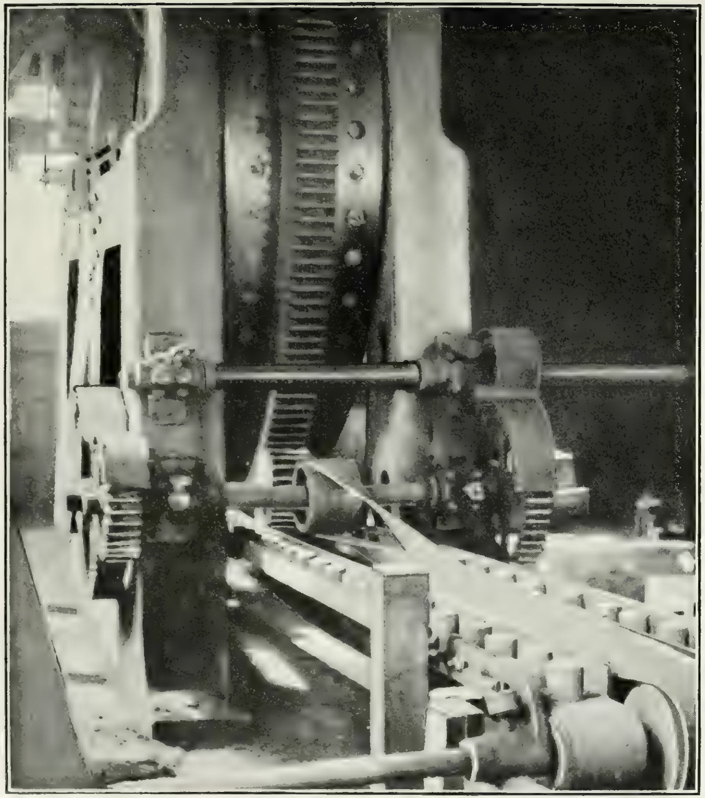
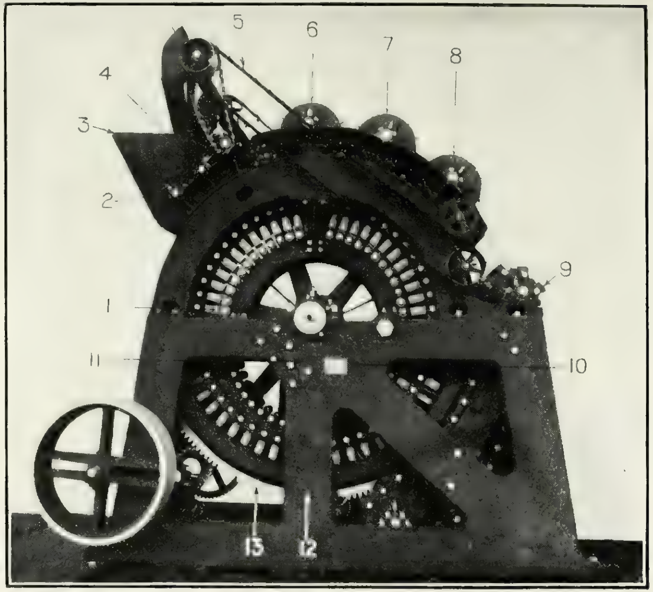
[a] Mills, J. E., Binders for coal briquets; investigations made at the fuel-testing plant, St. Louis, Mo. Reprint of U. S. Geol. Survey Bull. 343.



A. FRONT VIEW OF LADLEY BRIQUETTING PRESS.



B. SIDE VIEW.

1, One of the 108 rams; 2 and 4, shafts of mold-filling device; 3, feed box; 5, belt conveyor to return superfluous dust to feed box; 6, 7, 8, tamping wheels to fill molds under pressure; 9, link or anvil-blocks belt closing outer end of molds to permit application of pressure by rams; travels tangentially to mold wheel during part of revolution; 10, cams moving rams are behind frame at this point; 11, relief springs holding cams in place are attached to frame at this point; 12, point at which briquets are ejected from molds; 13, gear turning mold wheel.

Summary of fuels tested.

State and field No.	Kind and size of fuel.	Name of bed.	Locality.	County.	Railroad.	Station at which briquetting tests were made.	Page of bulletin on which tests are reported.
Alabama:							
No. 1	Bituminous, lump and nut	Mary Lee or Horse Creek.	1½ miles west of Horse Creek.	Walker	Frisco system	St. Louis	121
No. 2-B	Bituminous, run of mine	Jagger	Carbon Hill	do	do	do	122
No. 4	do	Youngblood or Coke	Belle Ellen	Bibb	Louisville & Nashville	do	123
Argentina, No. 1				Province of Mendoza.		do	125
Arkansas:							
No. 1	Semibituminous, over 1½-inch screen	Huntingdon	Huntingdon	Sebastian	Frisco system	do	126
No. 2	do	Hartshorne	Bonanza	do	do	do	126
No. 3	do	Jennie Lind	Jennie Lind	do	Missouri Pacific	do	127
No. 4	Semibituminous, slack	Denning	Denning	Franklin	do	do	128
No. 5	Semibituminous, half slack, half lump.	do	West of Coal Hill	Johnson	do	do	130
No. 6	Bituminous, slack coal	Jennie Lind	Jennie Lind	Sebastian	do	do	132
No. 7-A	Semibituminous, lump, over 2-inch perforated screen.	Hartshorne	Midland (4 miles southwest).	do	Midland Valley	do	(a)
No. 7-B	Semibituminous, slack, through 2-inch perforated screen.	do	do	do	do	do	132
No. 13	Bituminous, slack	(?)	Denning	Franklin	St. Louis, Iron Mountain & Southern.	do	133
California:							
No. 1	Subbituminous, run of mine	(?)	Tesla	Alameda	Alameda & San Joaquin.	do	(a)
Pittsburgh, No. 14	Brown lignite, run of mine		Ione	Amador	Southern Pacific	Pittsburgh	135
Colorado:							
No. 1	Subbituminous, run of mine	(?)	Lafayette	Boulder	Colorado & Southern, Burlington system.	St. Louis	143
Illinois:							
No. 1	Bituminous, over 1-inch screen	Herrin (Belleville, No. 6).	O'Fallen	St. Clair	Belt Terminal of East St. Louis.	do	143
No. 4	Bituminous, over 2-inch screen	do	About 1 mile west of Troy.	Madison	St. Louis, Troy & Eastern.	do	144
No. 5	Bituminous, slack	(?)	Collinsville	do	do	do	(a)
No. 6	Bituminous, run of mine	Jennie Lind	Coffeen	Montgomery	Toledo, St. Louis & Western.	do	(a)
No. 7-C	Bituminous, slack	Herrin (Belleville, No. 6).	Near Collinsville	Madison	Vandalia	do	(a)
No. 7-D	Bituminous, run of mine	do	do	do	do	do	(a)
No. 7-E	Bituminous, screened nut	do	Collinsville	do	do	do	146
No. 8	Bituminous, nut	(?)	Paisley	Montgomery	Big Four	do	(a)

[a] Tests described in Bull. 24, Bureau of Mines.

Summary of fuels tested—Continued.

State and field No.	Kind and size of fuel.	Name of bed.	Locality.	County.	Railroad.	Station at which briquetting tests were made.	Page of bulletin on which tests are reported.
Illinois—Continued.							
No. 9–A	Bituminous, run of mine	Herrin (Belleville No. 6).	Near Staunton	Macoupin	Litchfield & Madison	St. Louis	(a)
No. 9–C	Bituminous, slack	do	do	do	do	do	147
No. 10	do	Big Muddy	West Frankfort	Franklin	Chicago & Eastern Illinois.	do	(a)
No. 11–B	Bituminous, one-half run of mine, one-half lump coal.	do	Near Carterville	Williamson	Illinois Central	do	(a)
No. 11–C	Bituminous, one-half No. 4 washed coal, one-half No. 5 washed coal.	do	do	do	do	do	(a)
No. 12–B	Bituminous, size 5	do	Bush	do	St. Louis, Iron Mountain & Southern.	do	148
No. 14	Bituminous, lump, over 1½-inch bar screens.	Springfield (No. 5)	East side of Springfield	Sangamon	Illinois Central	do	(a)
No. 20	Bituminous, screenings	No. 6	Staunton	Macoupin	Litchfield & Madison	do	150
No. 21	Bituminous, lump, over 2¼-inch screen.	Herrin (Belleville No. 6).	Troy	Madison	St. Louis, Troy & Eastern.	do	150
No. 23–B	Bituminous, slack, through 2-inch perforated screen.	do	Donkville	do	do	do	151
No. 28–A	Bituminous, size 5, washed	Herrin (No. 6)	Herrin	Williamson	Illinois Central	do	152
No. 28–B	Bituminous, screenings, raw	do	do	do	do	do	153
No. 29–A	Bituminous, screenings, through 2-inch shaking screen.	Herrin (Belleville (No. 6).	Livingston	Madison		do	155
No. 29–B	Bituminous, run of mine	do	do	do		do	155
No. 30	Bituminous, nut, through 3-inch and over 2-inch shaking screen.	do	Shiloh	St. Clair	Southern	do	156
No. 31	Bituminous, screenings, over 1¼-inch shaking screen.	do	Worden	do	Wabash	do	158
No. 33	Bituminous, screenings, through 1½-inch shaking screen.	do	Trenton	Clinton	Baltimore & Ohio	do	159
Indiana:							
No. 1	Bituminous, run of mine	do	Mildred	Sullivan	Evansville & Terre Haute.	do	160
No. 1–B	Bituminous, screenings, through 1-inch screen.	do	do	do	do	do	161
No. 2	Bituminous, run of mine	No. 5	Booneville	Warrick	Southern	do	162
No. 5–B	Bituminous, screenings, through 1¼-inch bar screen.	do	Hymera	Sullivan	Evansville & Terre Haute.	do	162
No. 6–B	do	do	do	do	do	do	163
No. 19	Bituminous, screenings, through 1¼-inch stationary bar screen.	Brazil Block (top)	Diamond	Parke	Chicago & Eastern Illinois.	do	165
No. 20	do	Brazil Block (bottom)	Brazil	Clay	do	do	166

Indian Territory:							
No. 2	Bituminous, run of mine	Lower Hartshorne	Hartshorne		Rock Island system	do	167
No. 2-B	Bituminous, slack, through ⅝-inch shaking screen.	do	do		do	do	167
No. 2-C	Bituminous, lump, over 1-inch shaking screen.	do	do		do	do	167
No. 3	Bituminous, run of mine	McAlester	Edwards		do	do	170
No. 6	Bituminous, slack	do	Coalgate		Missouri, Kansas & Texas.	do	171
No. 9	Semianthracite; run of mine	(?)	Panama		Kansas City Southern	do	174
Iowa:							
No. 2	Bituminous; run of mine	Big Vein	Liberty Township	Marion	Wabash	do	(a)
No. 4	Bituminous; over 1⅜-inch screen	Mystic	Centerville	Appanoose	Chicago, Burlington & Quincy; Illinois Central; Chicago, Rock Island & Pacific; Chicago, Milwaukee & St. Paul, Iowa Central.	do	175
Kansas:							
No. 2	Bituminous; lump and nut	Weir-Pittsburgh	Yale	Crawford	Missouri Pacific	do	176
No. 2-B	Bituminous; slack	do	do	do	do	do	177
Kentucky:							
No. 1	Bituminous; run of mine	Straight Creek	Straight Creek	Bell	Louisville & Nashville.	do	178
No. 2	Bituminous; over ⅞-inch screen	No. 11	Earlington	Hopkins	do	do	179
No. 2-B	Coke breeze		do	do	do	do	180
Maryland:							
No. 2	Bituminous; run of mine	Pittsburgh	Lord	Allegany	Baltimore & Ohio	do	181
Missouri:							
No. 1	do		New Home	Bates	Frisco system	do	182
No. 3	Bituminous; slack		Mendota	Putnam	Burlington system	do	(a)
No. 10	Bituminous; screenings, through ¾-inch shaking screen.	Bevier	Bevier	Macon	Chicago, Burlington & Quincy.	do	183
Montana:							
No. 1	Black lignite (?); No. 4 washed nut.		Red Lodge	Carbon	Northern Pacific	do	184
New Mexico:							
No. 1	Subbituminous; run of mine	No. 3 and No. 3½	3 miles north of Gallup.	McKinley	Santa Fe system	do	185
No. 2	Subbituminous; slack	Otero, Thatcher, Crown Point.	1½ miles east of Gallup.	do	do	do	186
North Dakota:							
No. 1	Brown lignite; run of mine		Lehigh	Stark	Northern Pacific	do	187
Pittsburgh No. 11	Black lignite; run of mine	Upper	Scranton	Bowman	Chicago, Milwaukee & St. Paul.	Pittsburgh	189
Pittsburgh No. 13	do	do	Lehigh	Stark	Northern Pacific	do	191
Pittsburgh No. 15	Black lignite; 3-inch lump	do	Vanderwalker	Ward	Soo Lines	do	193
Pittsburgh No. 17	Black lignite; lump	do	4 miles south of Williston.	Williams	Great Northern	do	74

(a) Tests described in Bull. 24, Bureau of Mines.

Summary of fuels tested—Continued.

State and field No.	Kind and size o fuel.	Name of bed.	Locality.	County.	Railroad.	Station at which briquetting tests were made.	Page of bulletin on which tests are reported.
Pennsylvania:							
No. 3	Anthracite; culm					St. Louis	195
No. 15	Semibituminous; run of mine	Lower Kittanning, B, or Miller.	Wehrum	Indiana	Pennsylvania	do	197
No. 16	do	Lower Freeport or D	Hastings	Cambria	do	do	198
No. 18	do	Miller	Lloydell	do	do	do	199
No. 19	Bituminous	Pittsburgh	Herminie	Westmoreland	do	do	203
No. 20	Semibituminous	Lower Kittanning or B	Seward	do	do	do	205
No. 22	Bituminous	Pittsburgh	Huff	do	do	do	206
Jamestown No. 18	Anthracite; buckwheat size					Norfolk	207
Philippine Islands:							
Pittsburgh No. 112	Lignite; run of mine		Batan Island	Philippine Islands		Pittsburgh	208
Rhode Island:							
No. 1	Anthracite graphite coal; run of mine.	Cranston (?)	Cranston	Providence	New York, New Haven & Hartford.	St. Louis	219
Pittsburgh No. 19	Graphitic anthracite; lump	Cranston - Narragansett Basin.	do	do	do	Pittsburgh	219
Tennessee:							
No. 1	Bituminous; run of mine	Mingo or Ralston	Fork Ridge	Claiborne	Louisville & Nashville.	St. Louis	221
No. 4	do	Windrock or Dean	Oliver Springs	Anderson	do	do	222
No. 7–B	Bituminous; slack, through ¼ by 1-inch screen.	Wilder	Wilder	Fentress	do	do	223
No. 9–B	Bituminous; raw slack	Sewanee	Coalmont	Grundy	Nashville, Chattanooga & St. Louis.	do	225
No. 9–C	Bituminous; washed slack	do	do	do	do	do	225
No. 10	Bituminous; slack	Battle Creek	Orme	Marion	do	do	226
Texas:							
No. 1	Brown lignite; run of mine		Wootters Station	Houston	International & Great Northern.	do	60
No. 4	Lignite; run of mine	(?)	Hoyt	Wood	Missouri, Kansas & Texas.	do	227
Pittsburgh No. 7	Brown lignite; ¾-inch lump	"Big Vein"	3½ miles northeast of Rockdale.	Milam	International & Great Northern.	Pittsburgh	228
Pittsburgh No. 8	Brown lignite; ½-inch lump	(?)	2 miles southwest of Lytle.	Medina	do	do	229
Pittsburgh No. 9	Brown lignite; ¾-inch lump	Upper	6 miles west of Calvert	Robertson	do	do	232
Utah:							
No. 1	Bituminous; run of mine	(?)	Huntingdon Creek	Carbon		St. Louis	235
No. 2	Subbituminous; slack, through 1¼-inch screen.	Coalville, Ten Foot, or Grass Creek.	Coalville	Summit	Union Pacific	do	236
Pittsburgh No. 36	Subbituminous coal	Wasatch (?)	do	do	do	Pittsburgh	91

Virginia:							
No. 5-B	Semia anthracite; slack	Big seam	Blacksburg	Montgomery	Norfolk & Western	St. Louis	238
Jamestown No. 2	Semibituminous; run of mine	Pocahontas No. 3	Pocahontas	Tazewell	do	Norfolk	239
Jamestown No. 14	Semianthracite; culm	(?)	Merrimac	Montgomery	do	do	241
Washington:							
No. 2	Bituminous; lump	Roslyn	Roslyn	Kittitas	Northern Pacific	St. Louis	242
Pittsburgh No. 35	Subbituminous		Tono	Thurston		Pittsburgh	93
West Virginia:							
No. 3	Bituminous; run of mine	Upper Freeport	4 miles southeast of Morgantown.	Monongalia	Morgantown & Kingwood.	St. Louis	243
No. 6	Semibituminous	Fire Creek (Quinnimont).	Rush Run	Fayette	Chesapeake & Ohio	do	243
No. 7	do	Sewall	Sun	do	do	do	(a)
No. 9	Bituminous	Powellton	3 miles south of Powellton.	do	do	do	(a)
Jamestown No. 3	Semibituminous; run of mine	Thin vein Pocahontas	Davy	Hampshire	Norfolk & Western	Norfolk	244
Jamestown No. 5	do	Sewell No. 5	1 mile east of Sewell	Fayette	Chesapeake & Ohio	do	246
Jamestown No. 6	do	Sewell	Redstar	do	do	do	247
Jamestown No. 7	do	do	Derryhale	do	do	do	248
Jamestown No. 8	do	Quinnimont (Fire Creek).	Lawton	do	do	do	249
Jamestown No. 9	do	Sewell	Winona	do	do	do	251
Jamestown No. 10	do	Beckley	Stanaford	Raleigh	do	do	252
Jamestown No. 11	do	do	West Raleigh	do	do	do	253
Jamestown No. 12	do	Pocahontas No. 3	Switchback	McDowell	Norfolk & Western	do	255
Jamestown No. 13	do	do	Ennis	do	do	do	256
Jamestown No. 15	do	Fire Creek and Sewell	Minden	Fayette	Chesapeake & Ohio	do	257
Jamestown No. 16	do		Midvale	Doddridge	do	do	258
Jamestown No. 17	do	Pocahontas No. 3			Norfolk & Western	do	260
Wyoming:							
No. 1	Black lignite; over 5-inch screen		9 miles northwest of Sheridan.	Sheridan	Burlington system	St. Louis	261
No. 6	Subbituminous; run of mine	(?)	Kemmerer	Uinta	Union Pacific	do	263
Miscellaneous:							
No. 5	Coke breeze					do	264
No. 9	do					do	264

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[a] Tests described in Bull. 24, Bureau of Mines.

BINDERS USED.

In the course of the fuel-briquetting investigations of the fuel-testing plants, attention was of necessity given to binding materials. With very few exceptions the binder tests were confined to primary binding materials, and practically no attention was given to trials of patented binders. Coal-tar pitch has been and is at present the binder most generally used in this country and in foreign countries.

In the briquetting experiments at the three fuel-testing plants a binder called water-gas pitch has been used to a larger extent than any other, as it was available at satisfactory prices and in sufficient quantities. This binder has an advantage over coal-tar pitch in the proportion of free carbon present, which is usually less than 10 per cent, whereas in coal-tar pitch it often amounts to 30 to 40 per cent. As this free carbon or carbon dust has no binding qualities itself, it acts merely as a diluent of the pitch, and therefore the binder that possesses the lower proportion of free carbon should have the greater binding power, other factors being equal. On the other hand, good grades of coal-tar pitch may possess a higher percentage of the heavier distillates than water-gas pitches and thus offset the disadvantage of a high percentage of free carbon.

In general, it may be said that the best grades of coal-tar pitch for fuel-briquetting purposes are those made by distilling the pitch to such a point that some of the anthracene or "green oils" remain with the hard pitch in the still rather than by distilling all the oil and then reducing the hard pitch with the naphthaline or creosote oils, as is sometimes done in preparing "reduced" pitches.

The quality or hardness of the pitch to be used will depend on the location of the plant and the time of year at which the pitch is to be used. Generally speaking, that grade of pitch known as medium hard pitch is most desirable for briquetting fuels. For use in summer or in the hotter parts of the country in the winter months, a harder pitch should be used than in the winter or in the colder parts of the country.

There are two general methods of incorporating pitch binder with fuel to prepare a mixture for briquetting. The most general method is the one in which the pitch is ground and mixed with the fuel and the mixture heated by steam or air until the pitch is softened sufficiently to flow. In the other method, the pitch is melted separately from the fuel and the latter is heated to a temperature above the melting point of the binder, so that when they are mixed the pitch is easily and evenly distributed throughout the mass.

Although authorities differ as to the best manner of mixing pitch binder with the fuel, the bureau's experiments indicate that less pitch is required if it is not melted but only softened sufficiently to be "tacky," and the particles of coal are made to adhere by the particles of pitch and the pressure of the machine. An advantage derived from not heating the mixture too hot is that the briquet, when leaving the machine, will be cold enough so that the pitch will be somewhat hard, thus giving a maximum strength. Otherwise when the pressure is relieved there is a tendency for the compressed air and steam in the briquet to expand and cause cracks on its surface. There is a temperature for each grade of pitch that will give the greatest plasticity to the mixture and at the same time the greatest strength to the fresh briquet. With some types of equipment the mixture of fuel and pitch passes through a spiral cooling conveyor after leaving the heater and before reaching the press, and with this arrangement it is possible to "temper" the mixture to the desired consistency.

If pitch be melted to a thin liquid some of it will be absorbed by the coal particles, and although this result might be desirable when briquetting a fuel like lignite, it is not necessary and is therefore a waste of material in the case of anthracite and bituminous coals. The use of more pitch binder than is absolutely necessary to stick the particles together increases the cost of briquetting and adds to the smoke-producing qualities of the briquets.

Wherever possible it is best to mix the larger pieces of pitch and coal and pass them through the fine grinder together. By this treatment a more intimate mixture is obtained than if each is ground separately and mixed afterwards. It is much easier (especially in warm weather) to grind the pitch in mixture with the coal than by itself.

The tests applied to binding materials changed as the work progressed, so that the earlier tests were not made along the same lines as the later ones. Therefore the results of all of the tests of binders can not be included in one table. A description [a] of the binder tests made in the first part of the work at St. Louis is given here and the tabulated data of the later tests are given elsewhere.

BINDERS USED IN EARLIER TESTS AT ST. LOUIS.

It was found that one binder would give good results with one coal but could not be used with other coals. On account of the situation of the coal districts it is often necessary, for commercial reasons, to substitute another binder for one that under laboratory conditions would give good results. An attempt was made not only to obtain a binder with which the coal could be briquetted, but to devise a binder that would make briquetting commercially possible. The greatest difficulty was experienced with the various grades of lignite, most deposits of which are too remote from supplies of available binder to make it possible to utilize certain materials for binding purposes that would otherwise give satisfactory results.

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[a] Taken from Pratt, J. H., Briquetting tests: U. S. Geol. Survey Prof. Paper 48 (pt. 3), 1906, pp. 1394–1401.

The materials that have been tried as binders in the laboratory experiments and in the two briquetting machines include the following: Pitch of various grades, creosote, asphalt (hard and soft, crude and refined), asphaltic pitch, petroleum (both of paraffin and asphalt bases), molasses, lime, and clay.

Pitch is the residue left from the distillation of tar that is obtained (1) from by-product coke ovens, (2) from illuminating-gas plants, (3) from producer-gas plants, (4) from Pintsch-gas plants, (5) from water-gas plants, and (6) from petroleum-gas plants. Pitches made from the first three varieties of tar were tested and gave equally good satisfaction when approximately of the same composition. Petroleum-gas tar gave the best results.

There is considerable variation in the tars obtained by the various processes mentioned above, the pitch obtained from different batches of the same tar often varying greatly even when distilled to the same final temperature. In order to obtain a uniform grade of pitch it is necessary to keep the fire at approximately the same intensity, and it is usually considered advantageous to use the same still for the same tar. Tar obtained from by-product coke ovens differs in quality from tar made at illuminating-gas works, probably because the condensers of the former are kept at a temperature so high that the available benzole does not enter the tar, but is removed separately. It usually contains much more fixed carbon than that obtained from gas-house tars. It also contains more water than the other tars.

Pintsch-gas tar is obtained as a thin emulsion in water, from which it can be separated only by long standing in a tank at a temperature just below 212° F. The tar is composed largely of naphthalene and benzine.

The entire output of tar from many illuminating-gas and by-product coke plants is now purchased by pitch manufacturers. The price of coal-gas tar varies considerably, reaching at times 3 cents per gallon. The price of illuminating-gas tar, guaranteed to contain less than 10 per cent moisture, is 6 cents per gallon. An average sample of this tar contains 5.25 per cent of water, gives 14,172 British thermal units, and has a specific gravity of 1.21. Water-gas tar is sold at 4 cents per gallon, averages 6.75 per cent of water, and gives 15,325 British thermal units. Its specific gravity is 1.12. At present there is no market for Pintsch-gas tar, which has always been sold cheaper than water-gas tar. When dried, this tar contains 4 per cent of water, gives 12,304 British thermal units, and has a specific gravity of 1.18.

The pitches submitted to the plant for the experimental work varied considerably. The first pitch received was from the St. Louis works of the Barrett Manufacturing Co. The pitch was too hard and would not soften at a temperature low enough to be used satisfactorily in either the English or the American machine. The pitch did not contain a sufficient proportion of the creosote oils to give it the required binding qualities. Throughout this report this pitch is designated as pitch A. The second lot of pitch was received from the Chatfield Manufacturing Co., of Carthage, Ohio, and was somewhat harder than pitch A, indicating that a still greater percentage of the creosote and lighter oils had been driven off. This pitch is designated throughout this report as pitch X. Although these pitches would make briquets, it was necessary to use 13 to 18 per cent of them, whereas only 6 to 9 per cent of pitch containing the proper amount of light oils would be required with the same coals.

In order to obtain a pitch that would be satisfactory, some of the best tar from the producer-gas plant was heated until all the water was expelled. The boiling was continued until the residue became brittle when dropped into water having a temperature of 55° F. After bucking down, this pitch stuck together on standing one week in the laboratory. It is designated throughout this report as pitch Z. A long series of tests was then made with this pitch and various coals, and 6 per cent of it was found to make better briquets than 13 per cent of pitch X.

In order to demonstrate further that the right quality of pitch required a higher percentage of the creosote or adhesive oils than pitches A or X, experiments were made with hard pitch A and water-free producer-gas tar. These were combined in various proportions until a product was obtained that became brittle when dropped into water at 55° F. A sufficient quantity of this product to briquet 2 tons of coal was made, and it was found to give the results desired. This pitch will soften when held in the mouth; when first bitten it cracks and crumbles like spruce gum, but almost immediately becomes plastic and can be chewed like ordinary gum. This simple test, in nearly all cases, will determine whether a pitch is of the proper quality for use in briquetting. This pitch is designated throughout this report as pitch Y. Samples were sent to the Barrett Manufacturing Co. and the Chatfield Manufacturing Co. for duplication in quantity. The pitches received later from the Barrett Manufacturing Co. are designated in this report as pitches B, C, and D. Those received from the Chatfield Manufacturing Co. are known as pitches E, F, and G.

Another pitch that was furnished by the Barrett Manufacturing Co. was obtained as a by-product from the manufacture of gas from heavy petroleum. When hot this pitch has a marked odor of kerosene. It is lustrous and works well on a cool day, but is a little too soft in ordinary weather for experiments on the English machine.

This pitch is designated as pitch H throughout this report. Analyses of these pitches were made by E. E. Somermeier, with the following results:

Proximate analyses of pitches.

Kind of pitch.	Laboratory No.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
A	1161	0.47	47.93	50.79	0.81	[a] 0.62
B	1311	1.14	49.66	47.88	1.32	.70
C	1391	.88	62.75	35.84	.53	.57
D	1465	1.45	54.05	43.91	.59	[a] .56
E	1464	1.02	54.11	44.04	.83	[a] .66
F	1457	.57	52.98	45.31	1.14	[a] .80
G	1453	.60	52.53	45.62	1.25	[a] .70
H	1555	1.04	61.44	36.72	.80	....
X	1125	.33	59.07	39.44	1.16	.88

[a] Approximately determined.

Ultimate analyses of pitches.

Kind of pitch.	Laboratory No.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Sulphur.	Calorific value.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
A	1161	4.17	91.30	0.85	2.25	[a] 0.62	....
B	1311	3.97	90.89	1.05	2.07	....	8,782
C	1391	4.72	91.16	1.16	1.85	.58	8,937
D	1465	4.28	91.57	1.10	1.90	.56	....
E	1464	4.22	91.30	1.00	1.99	.66	....
F	1457	4.16	91.50	1.00	1.40	.80	....
G	1453	4.06	90.82	1.01	2.16	.70	....
X	1125	4.56	90.34	.99	2.07	.88	8,820

[a] Determined by Eschka method.

Although no definite conclusions can be drawn from these analyses, yet of the pitches distilled from the same tar, under like conditions, those with the highest percentage of volatile matter gave the best results in briquetting. Pitches E, F, and G, furnished by the Chatfield Manufacturing Co., made from the same tar and distilled under approximately the same conditions, showed binding power that increased from G to E according to the increase in the percentage of volatile matter and the decrease in the percentage of fixed carbon. Pitch B, which was made under entirely different conditions and from a different tar, is much lower in volatile matter and higher in fixed carbon than E, yet makes a better pitch for briquetting than either E, F, or G.

In order to obtain a more definite estimate of the influence of the composition of pitches on their binding qualities and their value in briquetting, a series of tests was made by distilling their volatile contents. The results are given in the following table:

Distillation of pitches.

Kind of pitch.	Laboratory No.	Quantity of pitch used.	Temperature at which first drop came over.	Temperature at which the last of the oil was observed to come off.	Percentage of oil.	Final temperature to which still was raised.	Residue.
		Grams.	°*F.*	°*F.*		°*F.*	
A	1161	200	380	385	1.36	400	Hard coke.
B	1311	200	351	...	7.38	400	Do.
D	1465	200	332	375	13.01	400	Do.
E	1464	200	350	370	1.91	400	Do.
G	1453	200	324	382	.96	400	Do.
X	1125	200	391	...	.71	400	Do.

The total percentage of oils given off during the distillation was determined with sufficient accuracy for comparative purposes. It will be seen from the above table that there is a decided increase in the percentage of oils in the pitches that gave the best results. Pitch X, which was the hardest pitch tested and gave the least satisfaction, contains only 0.71 per cent of volatile oil, whereas pitch D, which was the most satisfactory of those given above, contained 13.01 per cent of oils. Pitches A and E, made by different companies but very much alike and of about the same grade, were not good pitches for briquetting. Pitch G was harder than either A or E, and little, if any, better than pitch X. Pitch B, which was one of the better ones used, approaching D in quality, contained 7.38 per cent of volatile oils. The experiments have shown that from 7½ to 14 per cent of these oils is necessary in the pitches in order to give them the binding qualities desired in briquetting. Pitches with a higher percentage of these oils are too soft and can not be used to advantage. Again, the oils driven off at 315° F. and lower temperatures are the creosote oils, for which there is a large demand. They command a price of 5½ to 6 cents per gallon, or about $15 per ton. Creosote was mixed with some of the hard pitches for binding purposes, and the product gave satisfactory results.

ROSIN.

The cheaper grades of rosin can be used for binding purposes to as good advantage as the refined material. Rosin may, in some cases, be used to advantage for hardening as well as for binding purposes. It has been used with lime and pitch, and good briquets were made with this combination. It was found that a better quality of briquets could be made with a smaller percentage of a mixture of rosin and pitch as a binder than with pitch alone. In burning, there is little or no odor from the rosin, although there is some tendency to smoke. Lime was used with the rosin to prevent, if possible, the smoking of the rosin briquets.[a]

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[a] The present price of rosin, which approximates $30 a ton, indicates that it can not compete with pitch or binding purposes.

ASPHALT.

Refined California asphaltum of grade B was used in the experimental work, and is designated throughout this report as asphalt B1. Another asphalt product used had a rubbery consistency and is known as "kopak" No. 30. It is manufactured by the Raven Mining Co., of Texas, and is designated in this report as asphalt B2. An asphaltic pitch made by the Waters-Pierce Oil Co. at one of its Texas plants was also used and is designated as asphalt B3. Crude asphalt from Indian Territory (Oklahoma) is designated B4. The last-mentioned asphalt is altogether too hard, approaching a coke and containing only a small percentage of volatile matter. A soft asphalt was received from the Gulf Refining Co., of Port Arthur, Tex., and is designated throughout this report as asphalt B5. An analysis of this asphalt by E. E. Somermeier was as follows:

Analysis of soft asphalt (B5) from the Gulf Refining Co.

	Per cent.
Moisture	0. 00
Volatile matter	80. 75
Fixed carbon	19. 25
Ash	. 00
Total	100. 00

Another soft asphalt was furnished by John McNeil, Casper, Wyo., and is known throughout this report as asphalt B6. It was a soft, tough asphalt, which on cooling to about 40° F. became brittle. An analysis by E. E. Somermeier gave the following results:

Analysis of asphalt (B6) from Casper, Wyo.

	Per cent.
Moisture	0. 48
Volatile matter	78. 77
Fixed carbon	20. 75
Ash	. 00
Total	100. 00

PETROLEUM.

Petroleums of both paraffin and asphaltum bases may sometimes be used to advantage in briquetting. On account of lack of time, little experimental work was done with the petroleums. Those that were used were crude oil from Spindletop, Tex., produced by the Gulf Refining Co., and a petroleum, also from the Beaumont district, produced by the Great Southern Refining Co. The latter had a gravity of 15° B., with a flash test of 505 and fire test of 570. The two petroleums mentioned are designated P1 and P2 throughout this report. The only other oil that was tested in briquetting was a Kansas crude oil, which is designated throughout this report as P3.

MOLASSES.

A few experiments were made with molasses in order to determine the possibility of utilizing waste products from cane and beet sugar refineries in briquetting lignite and lignite coals that occur in the vicinity of the refineries. Although no positive results have been obtained with such waste products as a binder, the work has shown the probability that they can be so utilized.

LIME.

Lime was used in combination with both rosin and molasses and some encouraging results were obtained. With rosin the lime was used principally to prevent smoking. One of the main objections to using more than a small proportion of lime is the fact that it increases the percentage of ash in the fuel without raising its heating efficiency. On the other hand, it is one of the cheapest binders and may be obtained at places easily accessible to most of the coal districts.

CLAY.

A few experiments were made with clay in combination with other compounds in an attempt to obtain a suitable binder for lignite coals, but without success.

LABORATORY EXPERIMENTS AT ST. LOUIS.

In testing the value of the various binders for the briquetting of coal, a series of experiments with each was made in the laboratory by briquetting the mixtures on a hand press. Each mixture of coal and binder was heated in a glass assay crucible over a Bunsen burner. In most cases it was heated only to about 212° F., but when the binder was softened with difficulty the temperature was increased. Until the regular hand press was completed, the experiments were made on a screw press with a steel mold about three-eighths of an inch in diameter.

The various coals, after they had been heated with the different binders, were tested in the press, with varying pressures on the same mixtures. Thus, for each mixture there was a series of six briquets made, representing, respectively, a light pressure, a moderate pressure, a pressure of 2,500 pounds, a pressure of 4,000 pounds, and the maximum pressure of about 5,000 pounds. The quantity of mixture fed into the mold was also varied, so that some of the briquets made were only one-fourth of an inch long, whereas others were an inch long. All the briquets made with a particular mixture gave practically identical results with the same length of briquet, and there was usually only slight variation with briquets made under different pressures.

PITCH TESTS.

GENERAL RESULTS.

Special experiments were made with the different pitches, A, B, etc., and if there was considerable variation in their composition more complete experiments were made. All of the pitches mix with gas tars and creosote, making a product that resembles the softer pitches. They also mix with rosin in any proportion, giving a mass having the expected intermediate properties. They will not mix with any of the Kansas or Texas crude oils or the refined Texas petroleum (P2), or with Indian Territory (Oklahoma) asphalt (B4), California asphalt (B1), Texas asphalt (B2), asphaltic pitch (B3), or soft asphalt (B5). Experiments showed that rosin and oil would mix in all proportions, and such mixed masses of rosin and oil were tried in combination with the pitches, but on adding the pitch to this combined oil and rosin the oil was liberated and the resultant mass was granular and greasy, without any strength whatever. Another experiment showed that crude oil would neutralize the effect of clay in a coal, and although it was hoped that a combination of oil and pitch might be used, it was found that the crude-oil products would not mix with any of the tar pitches, and thus no positive results could be obtained by such combination.

The experiments made with pitch as a binder, when heated to 212° F., indicate that the results are better when there is a slight quantity of steam present. When coal and pitch, mixed with a small quantity of water, were heated in a clay crucible until steam began to come off freely and were then pressed, much better results were obtained than when the two were heated dry to the same temperature, or when the wet mixture was heated until all the water had been evaporated.

TESTS OF PITCH A.

Experiments were made in the laboratory with pitch A to determine its binding qualities. Nine per cent of this pitch was mixed with Arkansas No. 1 coal and squeezed to the limit of the screw press. The warm mixture yielded a highly polished cylindrical briquet, which, after remaining in a beaker of boiling water for two hours, showed no noticeable softening. This same mixture was further heated until the pitch began to smoke and was then put through the screw press. The resulting briquet was smooth and clean.

Seven per cent of pitch A with Arkansas No. 4 coal, when heated in an assay crucible and run through the hand press, made a fair briquet which burned well. Six per cent of this same pitch with Arkansas No. 6 coal, heated in the same way and with the maximum pressure of the hand press, made a crumbly briquet. Alabama No. 1

coal was also tested with pitch A, the coal having been previously crushed to pass a 60-mesh sieve. With 7 per cent of pitch A, when the mixture was heated so as nearly to burn the fingers, the resultant briquets were just beginning to cohere. With 9 per cent it made a well-pressed, coherent, but rough briquet. With 11½ per cent the briquets were little or no better, except that they were somewhat cleaner. With 20 per cent, when the mixture was only warm, but with a maximum pressure, the resultant briquet was good. All these briquets were, however, dirty.

The above experiments show that the best practical results with this hard pitch were obtained by using 9 per cent of it with a coal easily briquetted; with other coals the percentage should be much higher.

Pitch A was further tested with rosin, but no satisfactory results were obtained with pitch A and rosin.

TESTS OF PITCH B.

Pitch B was tested with West Virginia coking coal. With 3 per cent of pitch B a fair briquet was obtained. With 4 per cent the resulting briquet was a little better, and with 5 per cent a good briquet was made which had the desired lustrous fracture. With Arkansas No. 4 coal 6 per cent of this pitch was needed to give the desired results, and as this coal represents more nearly the character of the coals to be briquetted, 6 per cent was accepted as the percentage required of this and the similar pitches C and D to make a good briquet. A series of experiments was also made with this pitch and lime. The experiments indicated that there is no advantage in using lime with pitch in an attempt to reduce the percentage of pitch. If, however, some third substance that will react with the lime can be used it may be possible thus to produce a binder that will be cheaper than pitch alone and quite as satisfactory.

TESTS OF PITCHES C AND D.

Pitches C and D, which are similar to pitch B, were used with the formulas derived for B, and in nearly all cases the runs made on the English and American machines were satisfactory.

TESTS OF PITCH E.

Pitch E, which melts at 180° F., is a trifle too hard for satisfactory briquetting on the English machine and is not equal to pitches B, C, or D. Six, 7, 8, and 9 per cent of this pitch were tested alone on Illinois No. 4 coal. With 6 per cent the briquet was noncoherent; with 9 per cent an excellent briquet was made. With Arkansas No. 5 coal, which makes an excellent briquet with 6 per cent of pitch B, 8 per cent of pitch E was necessary to obtain a corresponding briquet.

Another series of experiments with pitch E was made with Kentucky No. 2 coal. The coal was crushed so that half would pass through a 20-mesh sieve and half through a 10-mesh sieve. With 7 per cent of pitch E a briquet was obtained that was just coherent; with 8 per cent the briquet was nearly satisfactory; but with 9 per cent an excellent briquet was obtained, similar to those made with the Illinois No. 4 coal.

TESTS OF PITCH G.

Pitch G, which melts at 196° F., is too hard (as are A and X) to be used alone in briquetting. With 1¼ per cent of creosote and 8 per cent of pitch G, a good briquet was obtained that disintegrated only slightly in the fire, and this formula was used in making a trial run on the English machine.

TESTS OF PITCH X.

Experiments were made with pitch X with 70 per cent of Pennsylvania No. 2 anthracite coal and 30 per cent of West Virginia No. 1 bituminous coal. To these mixed coals were added varying percentages of pitch X, until with 13 per cent the briquets were very satisfactory. Briquets were also made by using 12 per cent of pitch X with a mixture of coal containing 80 per cent of the anthracite and 20 per cent of the bituminous, and with a mixture of 60 per cent of the anthracite and 40 per cent of the bituminous. All of these mixtures made briquets that burned without any disintegration in a muffle. Pennsylvania No. 2 anthracite coal was also tested alone with 12 per cent of pitch and the resultant briquet was satisfactory. In all of the above cases the mixture was heated in an assay crucible until the pitch softened. No experiments on the English machine, however, could be made with these combinations.

TESTS OF PITCH Z.

The gas-producer pitch (Z) was tested with Arkansas No. 3 coal by using 6.7 per cent of the pitch. While hot these briquets were soft, but on standing one hour they became very hard and had a glossy or lustrous fracture. When tested in the muffle they burned without disintegration.

TESTS OF ASPHALT BINDERS.

Asphalts were used alone as a binder and also in combination with other compounds. A number of satisfactory results were obtained in the laboratory work, but only a few of the asphalts could be tried on either the English or the American machines, neither of which was adapted to the use of such mixtures.

RESULTS WITH CALIFORNIA ASPHALT.

California asphalt (B1) is brittle at ordinary temperatures and can be readily disintegrated. At 212° F. it softened slightly. It mixed readily with the Spindletop, Tex., petroleum (P1), and the residual product of Beaumont petroleum (P2) in all proportions, and can therefore be thinned to any consistency. A series of experiments was first made with 4 per cent of this asphalt with Arkansas No. 5 coal, from which a fair briquet was obtained. With 5 per cent the briquet was satisfactory, and with 6 per cent it was only a little better. By using 6 per cent of the asphalt, moistening the mixture, and then heating until steam came off, a briquet was obtained that was intermediate in quality between those made with 4 and 5 per cent mixed dry, and raised to a higher temperature. This indicates that to obtain the best results with this asphalt it would be necessary either to heat the mixture with superheated steam or to add crude oil.

The California asphalt was further tested with the Indian Territory No. 6 coal, and with 10 per cent of the asphalt an excellent briquet was obtained that was strong and sufficiently hard, but showed many clayey streaks. The Indian Territory briquets burned fairly well in the muffle.

RESULTS WITH "KOPAK."

The Texas asphaltic compound known as "kopak" (B2) softened slightly at 212° F. without becoming sticky. It melted at a rather high temperature, but was very adhesive. It can not be disintegrated readily in warm weather, but at a low temperature it can, with some care, be crushed. It is not affected by the crude Texas oil (P1) or the residual petroleum from Texas (P2). With the warm asphaltic pitch it mixed readily and little of this pitch was needed to make a soft, very sticky mass. With ordinary coal-tar pitches this asphaltic compound did not mix at all. With rosin the rubbery asphalt mixed readily, and the resulting product could be cracked rather easily. This asphalt has qualities that should make it a desirable binder, and it may perhaps be advantageously used in briquetting lignites.

The B2 asphalt was tested with a dry Texas lignite, 12 per cent of asphalt, heated, being used as a binder. The resulting briquet was tough and strong, but did not burn well, although it had more cohesion than a lignite briquet made with pitch. By using 12 per cent and heating with steam in the usual manner a briquet was obtained that was fully as strong as the one heated to a higher temperature. When the mold was warm a black, glossy briquet was produced. With 10 per cent of asphalt there was seemingly no difference in the appearance of the briquets. They disintegrated in the furnace, however, and for this reason this line of experimentation was not pursued further.

This asphalt was further tested by using 6 per cent in combination with 4 per cent of the asphaltic pitch (B3) and the dry Texas lignite. The resultant briquet was soft when taken from the mold. After standing one hour it presented a fair appearance, but had no coherence when burning, showing that no advantage is to be gained by adding the asphaltic pitch.

RESULTS WITH ASPHALTIC PITCH.

Asphaltic pitch (B3), made by the Waters-Pierce Oil Co. at one of its Texas plants, has excellent binding qualities and the right consistency to work easily. The pitch was tested first with Arkansas No. 5 coal, by using 6 per cent of pitch as a binder and heating to a moderate temperature in an assay crucible. The briquets were somewhat porous and not strong. By using 8 per cent of the pitch and moderate pressure a good briquet which stood up well in the fire was obtained. With Arkansas No. 6 coal, 6 per cent of this pitch made a tough, elastic, and rather soft briquet. This pitch does not give the degree of hardness that can be obtained by using coal-tar pitches.

Another test was made with Arkansas No. 5 coal by using 2 per cent of the asphaltic pitch and 4 per cent of lime as binder. The briquets showed little or no coherence when taken from the mold and no change in physical character at the end of 40 hours. Three per cent of pitch and 3 per cent of lime made a briquet that was only slightly better. Four per cent of pitch and 4 per cent of lime made a fair briquet, which was improved a little by an increase of pressure. Four per cent of pitch and 3 per cent of lime gave practically the same result. As there was seemingly no reaction between the pitch and the lime no advantage was gained in using lime.

A series of experiments was made with 5 per cent of the pitch and 1 per cent of rosin and Arkansas No. 2 coal. The briquet was somewhat soft when taken from the mold and did not harden in 24 hours. With 4 per cent of pitch and 2 per cent of rosin a briquet was obtained that was satisfactory in every way. Three per cent of pitch and 3 per cent of rosin gave seemingly the same results as 4 per cent of pitch and 2 per cent of rosin. With 2 per cent of pitch and 4 per cent of rosin a good briquet was obtained, which, however, was slightly brittle. One per cent of pitch and 5 per cent of rosin made a hard and strong briquet, but it was more brittle than the preceding. The briquets made from 4 per cent of asphaltic pitch and 2 per cent of rosin, and from 3 per cent of pitch and 3 per cent of rosin were of equal value. The 3-to-3 briquet is probably cheaper, and this ratio was adopted.

RESULTS WITH INDIAN TERRITORY ASPHALT.

Indian Territory asphalt (B4) did not soften in boiling water. It melted to a stiff, sticky liquid just below its ignition point. It is only slightly soluble in gasoline. At the boiling point there was seemingly no reaction between this hard asphalt and crude petroleums P1, P2, and P3. Neither was there any apparent reaction between this asphalt and melted rosin. With creosote it softened materially and when used with this in the ratio of 5 per cent of each with 90 per cent of Arkansas coal a fair briquet was obtained. With Pintsch-gas tar an apparent reaction took place which caused the separation of some of the contained water. One of the first tests made with this asphalt was to determine whether Kansas oil would have any softening effect on the asphalt, but no matter what quantity of oil was used, when heated with steam, only a noncoherent, greasy mass was formed. The asphalt was also tried alone with Arkansas coal by using 4 per cent of asphalt. The mixture was used dry and worked at a high temperature, but the resulting briquet was poorly coherent. With 6 per cent of asphalt the briquet was little or no better.

RESULTS WITH WYOMING ASPHALT.

Wyoming asphalt (B6) united readily with rosin. Two parts of asphalt and one part of rosin were melted together in a kettle and then cooled overnight. On a cool day the mass was very brittle, but became sticky with a rise in temperature. In using the mixture one to two parts of lime were added to prevent its becoming too soft while hot. The briquets crumbled easily in burning. A Wyoming lignite, undried, was tested with 8 per cent of the mixture (2 parts Wyoming asphalt with 1 part of rosin) and 1 per cent of slaked lime. This made a good briquet, which burned fairly well. With 7 per cent of the mixture and 1 per cent of lime the result was practically the same. With 6 per cent of the mixture and 1 per cent of lime the briquet was crumbly. A briquet made with 7 per cent of the mixture alone without lime appeared a little tougher when taken from the mold, but it did not burn so well. Seven per cent of the mixture and 2 per cent of slaked lime gave results similar to those with 7 per cent of mixture and 1 per cent of lime.

In testing this asphalt alone it was necessary to heat the coal in an assay crucible, add the fragments of asphalt, knead them together, and heat frequently. Six per cent of this asphalt alone made with Wyoming lignite a strong, tough briquet which was slightly earthy in appearance. When tested in the fire, however, the briquet fell to pieces at once.

ROSIN TESTS.

Rosin used alone as a binder produces brittle briquets. The results of the tests made with rosin and pitch are recorded under "Results With Pitch."

RESULTS WITH ROSIN AND PETROLEUM.

Rosin mixes with almost all of the crude oils and their residual products that were tested in the laboratory. It mixed readily with the rubbery asphalt B2, forming a still more rubbery mass, but did not unite at all with the Indian Territory asphalt B4. All of the oils and petroleums increased the toughness of the rosin, and the consistency of the resulting mixtures varied from that of wagon grease to that of sticky rosin. Five parts of rosin melted with 1 part of Kansas crude petroleum gave a tough mass.

A series of experiments was made with rosin and Kansas crude oil P3 and Indian Territory No. 6 coal. With 5 per cent of rosin and 1 per cent of P3 oil a soft briquet was obtained, which hardened after exposure. Six per cent of rosin and 1 per cent of P3 oil yielded a briquet that was slightly plastic, very tough and strong in a warm room, but brittle and somewhat crumbly in the cold. It required several hours to harden. Six per cent of rosin and 1½ per cent of P3 oil gave a briquet that could be bent in the fingers, but was no stronger than one made with 5 per cent of rosin and 1 per cent of oil.

Another series of experiments was made with equal parts of rosin and petroleum residue P2, which made a very sticky, plastic mass. With 6 parts of rosin and 4 parts of the petroleum P2, a mass was obtained that became hard when plunged into cold water. With 4 parts of rosin and 1 part of the petroleum P2, a mass was obtained that was slightly brittle at ordinary temperatures, but melted below 212° F. These proportions were therefore considered the best, and the mixture was tried with the Arkansas No. 5 coal by using 4 per cent of rosin and 1 per cent of the petroleum P2 as a binder. The resulting briquets were the best that were made in the laboratory and were hard enough to dent wood. When thrown violently against a cement floor, they broke across the grain and without producing any dirt. This briquet also burned exceptionally well.

The Indian Territory No. 6 coal was tried with a mixture of 3 per cent of rosin and 2 per cent of petroleum P2, but the briquet was oily, soft, and plastic. With a mixture containing 5 per cent of rosin and 2 per cent of petroleum P2 an excellent briquet was obtained. With 4½ per cent of rosin and 1½ per cent of petroleum P2 a briquet was made that was practically as good and represented the best proportion to be used with the coals of the type of Indian Territory No. 6. This briquet was nearly as good as those made with 10 per cent of the California asphalt B1.

RESULTS WITH ROSIN AND LIME.

With lime and rosin alone 15 per cent of lime and 85 per cent of rosin was the proportion required for a complete reaction. Rosin with unslaked lime sets after melting. If slaked lime be used, the reaction occurs at 212° F., and the mixture is light gray. This cement will soften and become sticky only at the melting point of lead. On cooling it is brittle, but stronger than rosin. With slaked lime rosin reacts and gives a satisfactory mixture up to 3 parts of rosin and 1 part of slaked lime.

RESULTS WITH ROSIN, LIME, AND PETROLEUM.

Rosin, slaked lime, and the petroleum residue P2 were mixed together in the proportion of 3 parts of rosin to 1½ parts of slaked lime and 1 part of petroleum P2. This mixture was tough and could be pulverized. Indian Territory No. 6 coal with 7 to 9.6 per cent of this mixture was heated with steam and when compressed made a medium hard briquet. It was not, however, tough enough nor did it burn satisfactorily.

Another combination was tried by using 3 parts rosin to 1½ parts slaked lime and 2 parts of Kansas P3 oil. This made a granular, nonbinding mass. With 2 parts of rosin to 1 of slaked lime and 1 of the P3 oil, a sticky, oily mass was obtained, but it was not at all tough.

A combination of rosin and the residual Beaumont petroleum P2 was made considerably tougher by the addition of lime, and for this combination relatively more lime was needed than when rosin alone was used. The best combination obtained was 6 parts of rosin to 3 parts of slaked lime and 2 parts of petroleum P2.

With Kansas crude oil no positive results could be obtained. Six parts of rosin, 3 of lime, and 4 of the Kansas oil P3 gave a greasy, granular mass without any apparent binding properties. With 3 parts of oil instead of 4 there was obtained a sticky mass, which, however, had no strength.

RESULTS WITH ROSIN AND SULPHURIC ACID.

Rosin was tested with sulphuric acid, the dilute acid having no effect on the rosin. Concentrated acid reacted with it, evolving SO_2 and forming a stiff, bright-red paste. When the paste was added to water there was formed a pink, soapy precipitate. Lignite was tested with 10 and with 13 per cent of this mixture, and fair briquets were made in each case. These softened slightly on standing and disintegrated in the fire. They were of about equal quality and equivalent to a briquet made with 12 per cent of rosin.

PETROLEUM TESTS.

All of the crude oils and petroleums can be stiffened to some extent by being mixed with rosin or hard pitch. None of the petroleums and oils that have been tested, however, could be used alone in briquetting any of the coals. Most of them were too fluid and had little or no binding qualities.

TESTS WITH MOLASSES.

The molasses experimented with in the laboratory can be bought in any market. It was always used in combination with lime. Thick molasses was diluted with twice its weight of water, and the lime was slaked to a paste with twice its weight of water. When these two reagents were mixed they had no apparent reaction until they were dry. By using 1 part of water to 1 of molasses and 2 of lime there was no apparent excess of either, and the mixture set at once to a rather hard cement similar to plaster of Paris. A series of experiments was made with Arkansas No. 6 coal by using slaked lime equivalent to 5 per cent of unslaked lime, diluted molasses equivalent to 1 per cent of the undiluted, and 94 per cent of the coal. The briquets were somewhat friable when taken from the mold, but became hard after standing 6 hours, and in 24 hours they were hard and strong. When immersed in water, they remained intact for about 48 hours, when they began to crumble. With a mixture equal to 3 per cent of unslaked lime and 3 per cent of undiluted molasses with 94 per cent of the coal, a briquet was obtained that was rather soft when first taken from the mold, but became hard in 5 hours. It burned with intumescence. With 1 per cent of lime and 5 per cent of molasses, the resultant briquet hardened slowly and at the end of 48 hours was tough and elastic, but not hard. At the end of seven days it had become extremely hard. In breaking it had a lustrous fracture and powdered only slightly. When tested in water, it softened and weakened only after several days. This ratio, 5 of molasses and 1 of lime, gave the best results.

Another test was made by mixing dry 4 per cent of quicklime with the coal and then adding 3 per cent of the molasses that had been previously diluted. The briquets as taken from the mold were soft and crumbly, having little or no cohesion. A brown Texas lignite, one-half crushed to pass through a 10-mesh sieve and the other half to pass through a 20-mesh sieve, was dried and tested, with the molasses and lime in the ratio of 5 to 1. The lime was first slaked to produce a dry, white powder, and the molasses was diluted with an equal weight of water. The very fine slaked lime equivalent to 1 per cent of unslaked lime and the lignite were mixed dry and then the diluted molasses, equal to 5 per cent of the pure molasses, was thoroughly mixed, a little at a time, with the mixed lime and lignite, enough extra hot water being added to thoroughly moisten the mass. The main difficulty was in making the lignite moist. With 5 per cent of molasses and 2 per cent of lime, the resultant briquet was just coherent, and many small intersecting cracks developed when the pressure was relieved. On standing 48 hours the cracks had not enlarged and the briquets were hard, brittle, glossy, and brown. With 7 per cent of molasses and 2 per cent of lime, the briquets were similar to the others when first taken from the mold, but became slightly harder and darker in 48 hours. With 7 per cent of molasses and 4 per cent of lime fewer cracks developed when the pressure was relieved, but the briquets were still soft. In 48 hours, however, they were noticeably stronger and blacker than those of either of the other two mixtures. With 10 per cent of molasses and 3 per cent of lime similar cracks developed on relief of pressure, and on standing 48 hours the briquets were as hard as those with 7 and 4 per cent, respectively. With 14 per cent of molasses and 4 per cent of lime the briquet obtained was fair when first taken from the mold. It was somewhat crumbly, however, and at the end of 48 hours showed little change. Its character was not changed by using the extreme pressure obtainable on the screw machine. With 12 per cent of molasses and 4 per cent of lime the briquet was better, but still not strong while fresh. In 48 hours it had hardened somewhat, but had developed many of the drying cracks. With 16 per cent of molasses and 2 per cent of lime there was an excess of molasses, this being squeezed out under pressure. This briquet was fairly good while fresh, but became too brittle on drying. With a higher percentage of lime there was less tendency to crack, and although in the present series of experiments little lime was used in excess of the proportion required for forming calcium saccharate, it may be that a further addition of lime would make a briquet that would behave better in the fire.

TESTS WITH WAX TAILINGS.

A sample of wax tailings received from the Standard Oil Co. was combined with Arkansas coal. With 98 per cent of coal and 2 per cent of wax no coherence was established under moderate pressure. With 4 per cent of wax, either hot or cold, an elastic briquet was obtained which was fairly clean, but yielded under slowly applied pressure. The briquets were tested in a muffle and seemed to burn perfectly. With additional pressure a briquet (containing 4 per cent of wax) was obtained which, although it had no greater strength than the other, was smooth and clean. With 5 per cent of the wax and with light pressure, a briquet was obtained that was rather sticky and showed an excess of wax by sticking to the plunger.

The wax was also tried with some of the harder pitches. With 1 per cent of wax and 3 per cent of pitch X a noncoherent briquet was obtained; 1 per cent of wax and 5 per cent of pitch X produced the same result, regardless of the pressure used; and with 2 per cent of wax and 4 per cent of pitch X a briquet was obtained similar to the one in which 13 per cent of pitch X alone was used. It was, however, not a satisfactory product.

TESTS WITH ACID SLUDGE.

Some acid sludge was received from the Gulf Refining Co., of Port Arthur, Tex. It was mixed with water, producing a weak acid solution, which did not seriously attack iron. Part of the sludge was a thin, greasy mass, and the remainder was rubbery and granular. The two parts did not mix when they were heated to the melting point. The stiffer part of the sludge did mix with melted rosin, and this mixture resembled the rubbery asphalt B2.

TESTS WITH LIME.

No experiments were made with lime alone, as the percentage required for making a coherent briquet was so high as to preclude entirely its use as a binder.

TESTS WITH CLAY.

Clay alone was tried up to 8 per cent, but in no case was a briquet obtained that would hold together on drying, although the clay used was a superior potter's clay.

COALS USED IN TESTS.

TESTS WITH COLORADO NO. 1.[a]

Colorado No. 1 coal without previous drying was tried with pitch D. With 7 per cent of the pitch the briquet showed little cohesion; with 9 per cent a fair briquet was obtained; and with 10 per cent a good one was made, which stood up fairly well in the fire. With 11 per cent the briquet was better than with 10, but it was decided to use 10 per cent in making a run on the English machine.

TESTS WITH TEXAS NO. 1.[b]

On account of the large areas of Texas No. 1 lignite and the importance of utilizing it as a fuel, many experiments were made in the laboratory in the effort to devise, if possible, a practical binder that could be used for briquetting it. It was first tried with pitch alone and then with various combinations, the results of the tests being largely unfavorable.

Results with pitch binder.—The lignite without previous drying was first tried with pitch B; it was crushed so that one-third was 40 mesh, another third 20 mesh, and the last third 10 mesh. With 6 per cent of pitch B heated in an assay crucible, without the addition of any water to make steam, a noncoherent briquet was obtained.

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[a] See table, p. 37.

[b] See table, p. 40.

Some of the lignite dry was briquetted with 6 per cent of pitch B, without steam. The resultant briquet was noncoherent. With steam, however, a slightly better briquet was made. With 10 per cent of pitch B and steam a briquet was obtained that was fair when taken from the mold, but when tested in the fire, fell to pieces. With 12 per cent of pitch B a briquet was obtained that was also fair when fresh from the mold, but this also disintegrated immediately when placed in the fire. Kansas crude petroleum P3 was added to the lignite-and-pitch mixture without beneficial results.

Results with asphaltic pitch and rosin.—The next experiments were with asphaltic pitch B3 and rosin. With 3 per cent of pitch, 3 per cent of rosin, and 94 per cent of dry lignite, molded under very high pressure, a briquet only just coherent was obtained. With 4 per cent of this pitch and 4 per cent of rosin a fair briquet was obtained. Five per cent of the pitch and 5 per cent of rosin gave a fairly strong briquet, which crumbled slightly. With 6 per cent of each a briquet was obtained that was satisfactory physically, but crumbled in the fire. Ten per cent of pitch and 2 per cent of rosin, or 2 per cent of pitch and 10 per cent of rosin, made fair briquets, but not equal to the 6 to 6. All of the briquets made with the asphaltic pitch and rosin crumbled in the fire.

Results with rosin and lime.—Another series of experiments was made on this lignite with rosin and lime. With 6 per cent of rosin, 2 per cent of quicklime, and 92 per cent of the dry lignite, heated with steam, a briquet was obtained that had little or no coherence. With a mixture of 8 per cent of rosin and 88 per cent of lignite, to which was added 4 per cent of lime that had been boiled in water, a fair briquet was obtained. If this mixture is quite dry and is squeezed immediately on mixing, it will stand up in the fire better than a briquet made with rosin alone, but it is too soft to be handled.

Another sample of the lignite was crushed to 10 and 20 mesh fineness and heated until it was charred black. Twelve per cent of rosin and 2 per cent of lime, mixed in boiling water, when combined with the lignite, made a briquet that was excellent physically but disintegrated in the fire. Briquets made of the lignite, previously mixed dry with 12 per cent of rosin and 2 per cent of quicklime and heated with steam, cracked through the center when the pressure was relieved, and fragments tested in the fire disintegrated completely. The charred lignite was then ground to 60-mesh fineness and tested with 10 per cent of rosin and 2 per cent of lime, but there was no coherence at all in the briquet. With 12 per cent of rosin and 2 per cent of lime a poor briquet was obtained from this finely powdered material—one much inferior to that made by using the coarser charred lignite and the same ratio of rosin and lime. It also disintegrated completely in the fire.

It was thought that perhaps by mixing a bituminous coal with the lignite the binder would be more effective in holding the particles of lignite together. A mixture containing 10 per cent of Pocahontas coking coal, 8 per cent of rosin, 2 per cent of lime, and 80 per cent of the Texas lignite was briquetted. A briquet was obtained that was physically satisfactory, but it did not stand up in the fire any better than the others.

Results with lime.—The Texas lignite with 8 per cent of lime alone and steam made a briquet that was good when first taken from the mold, but on drying it began to crumble, indicating that lime, except when used in very large quantity, would not successfully briquet this lignite.

Results with asphalt.—Another series of experiments was made with the rubbery asphalt B2. With 12 per cent of the asphalt an excellent briquet was obtained by heating it with the lignite and without steam. The briquet was smooth and hard, but in the fire acted like the lime-rosin briquets and crumbled. With 12 per cent of the asphalt heated with steam the briquet was also physically good, and when the mold of the press was warm the resultant briquet was black and glossy. With 10 per cent of the asphalt and steam the briquet was just as good. It did not, however, stand up well in the fire. With 6 per cent of asphalt and 4 per cent of the asphaltic pitch B3 and steam the resultant briquet was almost noncoherent while warm, but became stronger on standing one hour. It was a fair briquet, but disintegrated in the fire.

Results with petroleum and rosin.—The lignite was also tested with rosin and the petroleum P2. With 9 per cent of rosin and 3 per cent of petroleum the briquets expanded immediately upon relief of pressure and large cracks developed. The cracks closed as the briquet cooled and the result was a briquet of fair hardness and strength; however, it disintegrated in the fire. With 7 per cent of rosin and 5 per cent of petroleum P2 the resultant briquet was too soft, showing the need of more rosin in the mixture. Some cracks developed, as in the previous briquets, and in burning, the briquet disintegrated completely. With 9 per cent of rosin, 3 per cent of petroleum P2, and 3 per cent of slaked lime, a good briquet was obtained that did not expand and crack upon relief of pressure. It burned in the fire with some cohesion, but was no better than the rosin and lime alone, and there was no apparent advantage in adding the petroleum.

TESTS WITH WEST VIRGINIA NO. 3.[a]

West Virginia No. 3, a good coking coal, was tried in the laboratory to determine what could be done toward briquetting it without any binder whatever. Heated to 212° F. and then subjected to the maximum pressure on the hand press, a fair briquet was obtained without any binder. It was not strong, however, and caked in burning.

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[a] See table, p. 41.

When the coal was heated until it began to smoke, beautiful lustrous briquets were obtained, which were little stronger than the previous ones. When heated until caking began and then subjected to the maximum pressure an excellent briquet was obtained.

TESTS WITH OTHER COALS.

Many other coals were tested in the laboratory and it was found that in nearly all cases a coking coal could be briquetted without the introduction of any binding material. In these experiments it was noted that the coal needed to be heated until it began to cake and that the hot coal had to be fed direct to the press, as even slight cooling seemed to diminish its briquetting properties. Another peculiarity indicated by a number of experiments was that after the coal had been heated until it began to cake and was then cooled and reheated it lost some of its briquetting properties.

BINDERS USED IN LATER ST. LOUIS AND NORFOLK TESTS.

In view of European tests and the results of previous experiments at St. Louis no binder was investigated except two of the pitches derived from the distillation of the tar obtained as a by-product in the manufacture of illuminating gas, namely, water-gas pitch (abbreviated to W. G. P.) and coal-tar pitch (abbreviated to C. T. P.). In order to obtain data that would be comparable, all briquets in any one lot were made with 6 to 8 per cent of the same binder.

The "flowing test" used at St. Louis for determining the hardness of the pitch was made in the following manner: The bulb of the thermometer was covered with a thin layer of melted pitch, which was allowed to harden. The thermometer was passed through a cork fitted in the mouth of a test tube, so that the bottom of the thermometer bulb was held 2 inches from the bottom of the tube. The test tube was then held in a vertical position in a beaker of boiling water. As the pitch became soft it gradually dropped from the thermometer in the form of a thread, and the temperature recorded when this thread reached the bottom of the test tube was called the "flowing point."

A method of determining the melting point of pitches that was used in testing some of the binders is more practical than the method given above. It is an English method, devised by F. G. Holmes,[a] the details being as follows:

Several pieces of pitch are selected from different parts of the sample and cut into ½-inch cubes. The cubes are supported on 20-gage wires by heating the ends of the wires and pressing them into the pieces of pitch. They are then suspended in a 500-c. c. beaker of water, and heated by any convenient means at a uniform rate of 5° C. (9° F.) per minute. The cubes are placed on a level with the bulb of the thermometer; as the temperature rises the pieces of pitch are removed from time to time and twisted or squeezed with the fingers and the temperatures noted at which they become:

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[a] Thorpe, Edward, Dictionary of applied chemistry, 1913, vol. 4, p. 290.

(1) Soft, so that the pitch can be readily twisted around several times.

(2) Very soft, so that the pitch yields to a very light pressure of the fingers.

(3) Fused, so that the pitch melts off of the wire.

Soft pitch softens at 104° and melts at 140° F. Moderately hard pitch softens at 140° and melts at about 176° F. Hard pitch softens at 176° and melts at about 248° F. For this type of pitch it is necessary to use a bath of oil or glycerin in place of the bath of water in which to heat the cubes.

A fractional distillation of the pitch was made as another verification of its quality. From this distillation the oils coming off under 572° F., between 572° and 680° F., and between 680° and 743° F. were recorded. Pitch that at the temperature of the mouth could be bitten nearly through before breaking proved the most satisfactory binder for most coals briquetted. The results of the tests of binders used in the later briquetting tests at St. Louis and Norfolk are given in the following table:

Tests of pitches used at St. Louis and Norfolk.

Laboratory No.	Lot No.	Extracted by carbon bisulphide.	Heat value.	Free carbon.	Flowing point.	Distillation test.				Kind of pitch.
						Oils up to 572° F.	Oils from 572° F. to 680° F.	Oils from 680° F. to 743° F.	Total oils up to 743° F.	
			B. t. u.	*P. ct.*	*°F.*	*P. ct.*	*Per cent.*	*Per cent.*	*Per cent.*	
2735	......	58.56	....	41.44	187	(a)	(a)	(a)	(a)	C. T. P.
2729	......	61.20	....	38.80	255	(a)	(a)	(a)	(a)	C. T. P.
2748	......	89.20	....	10.70	144	(a)	(a)	(a)	(a)	W. G. P.
2933	......	64.20	15,937	35.70	176	(a)	(a)	(a)	(a)	C. T. P.
3258	1	80.27	16,373	19.73	179	3.66	12.30	15.23	31.19	W. G. P.
3257	2	84.10	16,137	15.90	163	.76	11.28	12.78	24.82	W. G. P.
3296	3	82.43	16,427	17.58	171	2.00	14.0	8.50	24.50	W. G. P.
3293	4	63.64	15,941	36.36	165	3.08	11.57	11.82	26.47	C. T. P.
3410	5	79.98	16,478	20.02	175	.85	15.21	9.11	25.11	W. G. P.
3486	6	85.57	16,407	14.43	187	1.75	6.00	17.00	24.75	W. G. P.
3623	7	69.26	16,027	30.74	165	.85	11.15	10.15	22.15	C. T. P.
3624	8	89.60	16,193	10.40	172	1.25	10.35	8.40	20.00	W. G. P.
3692	9	69.71	16,103	30.29	158	1.89	10.90	10.03	22.82	C. T. P.
3885	10	95.20	16,870	4.80	140	1.43	14.83	18.18	34.44	W. G. P.
3962	11	77.79	16,196	29.21	159	3.00	12.75	10.75	26.50	W. G. P.
4120	12	97.70	17,060	2.30	154	.75	11.25	17.25	29.25	W. G. P.
4318	13	90.42	16.744	9.58	165	1.00	11.10	13.50	25.60	W. G. P.
4319	14	66.25	16,139	33.75	158	2.75	10.35	9.90	23.00	C. T. P.
4543	15	99.66	16,969	.36	144	1.62	17.31	20.12	39.05	W. G. P.
4683	16	89.31	16,637	10.69	162	1.28	11.64	16.06	28.98	W. G. P.
4625	17	90.56	16,576	9.44	156	1.61	9.56	14.30	25.47	W. G. P.
4806	18	96.90	16,864	3.10	144	1.09	9.44	15.23	25.76	W. G. P.
4879	19	94.50	16,805	5.50	126	1.33	16.53	15.15	33.01	W. G. P.
4825	20	100.00	17,156	.0	115	.46	1.05	4.25	5.76	(b)
5458	21	92.92	16,893	7.08	189	.88	12.34	22.44	35.66	W. G. P.
5563	22	90.33	16,718	9.67	201	1.45	10.32	11.30	23.07	W. G. P.
5939	23	98.13	16.781	1.87	194	1.87	4.21	14.54	20.62	W. G. P.
5941	24	98.44	16,978	1.56	196	1.71	14.05	16.20	31.96	W. G. P.
5940	26	96.60	16.780	3.40	178	1.27	9.88	17.75	28.90	W. G. P.
12009	28	64.24	15,608	35.76	158	24.0	6.19	3.53	33.82	C. T. P.

[a] Data lost in fire.

[b] Wax tailings.

Percentage of binder.—In handling a given sample of coal various percentages of binder were used in briquetting lots of 600 pounds. In all cases the fuel and the binder were weighed separately, and the percentages of binder given are taken from these figures. The extraction analyses by carbon bisulphide, the results of which for binders are given in the above table, were made from carefully selected samples of coals, pitches, and briquets, and the percentage of binder in the finished product was calculated from these determinations.[a]

The flour used as a binder at Norfolk (laboratory No. 6110) had the following approximate analysis:

	Per cent.
Moisture	13.30
Volatile combustible	72.30
Fixed carbon	13.50
Ash	.90
Sulphur	.10

Its heating value was 6,998 British thermal units.

OTHER BINDER INVESTIGATIONS.

In the laboratory investigations of J. E. Mills the substances named below were tested as binding materials in the manufacture of briquets.

INORGANIC BINDERS.

Some inorganic materials used as binder are: Clay, lime, magnesia, magnesia cement (magnesia oxide and magnesium chloride), plaster of Paris, Portland cement, natural cement, slag cement, water glass.

ORGANIC BINDERS.

Some of the organic materials used as binders are:

(1) Wood products, such as rosin, pitch (rosin and tar), pine tar, hardwood tar, Douglas fir tar, wood pulp, sulphite liquor (from paper mills).

(2) Sugar-factory residues, such as beet pulp, lime cake, beet-sugar molasses, cane-sugar molasses.

(3) Starch, such as corn starch, potato starch.

(4) Slaughterhouse refuse.

(5) Tars and pitches from coal, such as blast-furnace tar, producer-gas tar, illuminating-gas tar (from coal), by-product coke-oven tar, coal-tar creosote, various grades of pitches from various tars.

(6) Natural asphalts, such as impsonite, gilsonite, maltha, refined Trinidad, refined Bermuda, hard and refined or gum (from impregnated sandstone, etc.).

(7) Petroleum products, such as crude oil, residuum (asphalts, etc.), water-gas tar, water-gas tar pitch, wax tailings, acid sludge, asphalt tar, Pintsch-gas tar, Pittsburgh flux.

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[a] See description of extraction test under heading "Tests Applied to Briquets."

CHARACTER AND RESULTS OF THE INVESTIGATIONS.

These investigations related not only to the nature and the amount of the binder necessary for making satisfactory briquets with each of the several coals tested, but also to the extent to which the binding quality of certain of these materials might be improved by the admixture of another binding material or another variety of coal.

Unless otherwise stated, 20 grams of each coal was mixed with the different percentages of the binding material and placed in a Battersea crucible. A small proportion of water was then added and the mixture heated with sufficient stirring to thoroughly mix the binder and the coal until steam came off freely and only a small proportion of water was left. A part of the mixture, while still hot, was pressed in a small laboratory hand press, at a pressure of 3,500 to 4,000 pounds per square inch. Each briquet weighed approximately 5 grams.

The use of inorganic binding materials is not likely to prove practicable under ordinary conditions, except when coking coals can not be obtained to mix with noncoking coals. A small percentage of inorganic materials (such as magnesium oxide or carbonate, or plaster of Paris), if added to other binding materials, may cause the briquets to hold together better in the fire.

Of the more specific results in the testing of different binding materials the following tentative statements are made, pending further investigations:

The use of clay, lime, and cement as binding materials was found entirely unsatisfactory, for the reason that they added largely to the ash constituent of the briquet. The briquets made with these binders disintegrated on exposure to water and weather. To waterproof them by soaking in oils, etc., was found difficult and expensive. Water glass (or sodium silicate) was also unsuitable for use in this connection.

Briquets containing 4 to 6 per cent of magnesium oxide used as a binder held together satisfactorily in dry weather and in the fire, but they disintegrated on exposure to rainy weather or when immersed in water.

In the tests with 2 to 12 per cent of plaster of Paris used as a binder, the briquets made were hard but brittle, and quickly disintegrated. Three per cent of magnesia mixed with 6 to 8 per cent of water-gas tar pitch seemed to make a stronger briquet than the same percentage of pitch used alone; but the improvement in the quality of the briquets is not considered sufficient to cover the additional cost of the magnesia and the additional percentage of ash that it brings into the briquet.

None of the sugar-factory residues was considered satisfactory as a binding material. The briquets made with them disintegrate on exposure to the weather, and no cheap waterproofing has as yet proved satisfactory.

None of the wood products, when used alone, was regarded as satisfactory. Some of these materials used in combination with other binders gave results of some promise and deserve further investigation.

The tests made using 0.5 to 3 per cent of starch as a binding material with different coals gave strong briquets. They were smokeless and held together in the fire until completely consumed; but these briquets went to pieces when wet or exposed to the weather for a considerable period of time. Experiments as to the possibility of cheaply waterproofing the briquets bound with starch, so as to make them hold together when exposed to water, were sufficiently successful to warrant further investigation in this direction. Starch is obtainable in large quantities and can be produced in almost any part of the country. Crude starch can probably be obtained at less than $20 per ton. At this price the use of 1 per cent of starch as a binder would add only 20 cents per ton to the cost of the briquets.

The scarcity and high price of slaughterhouse refuse would prohibit its use as a binding material for briquets. Satisfactory results were not obtained in the tests.

The tests with coal tars and the different grades of pitch made from those tars indicated that probably in the pitches the most satisfactory binders for the manufacture of briquets will be found; and that these can be made at a price that will bring the cost of the binding material used to not more than 50 to 75 cents per ton of briquets. Briquets made from a majority of the bituminous coals with a good grade of pitch as a binder burn well and are sufficiently strong to bear ordinary handling. They will stand exposure to the weather for a number of years without serious deterioration. The supply of pitch is large, and can easily be increased. The price now ranges from $9 to $11 per ton. The pitches obtained from different plants and those obtained at different times from the same plants vary considerably, not only in their boiling points, but in other respects; and in the case of similar pitches the percentage necessary for the proper working of different coals seemed to vary according to differences in the quality of the coals. It was found to be better to mix with a noncoking coal 10 to 20 per cent of a coking coal, rather than to increase the percentage of pitch.

In the investigation of the asphalts as binding materials, impsonite from the Indian Territory (Oklahoma) was rather unsatisfactory. In a number of tests with noncoking coals the result was improved by the addition to such coal of 5 to 10 per cent of impsonite in addition to 3 to 5 per cent of ordinary pitch or some other binding material. Four to eight per cent of gilsonite and other asphalts from Utah gave fairly satisfactory results as binders. These materials are found in Utah and elsewhere in large quantities. The price at present is too high to permit their extensive use.

Experiments with several other asphaltic materials were not altogether satisfactory. Asphaltic tar yielded fairly good results as a waterproofing material in briquets made with starch.

Four to six per cent of maltha (a liquid asphalt) used as a binder yielded fairly satisfactory results with coking coals. With noncoking coals it was insufficient.

Crude petroleums have been tested as binding materials, with satisfactory results. Six to eight per cent of asphaltic petroleum was used successfully in waterproofing briquets made with a starch binder. It is doubtful whether such use would prove entirely satisfactory on a commercial scale.

The petroleum residuums proved to be successful binding materials somewhat in proportion as the percentage of asphalt in them increased. That obtained from the Gulf Refining Co., of Port Arthur, Tex., melted at a temperature of 212° F., and about 99.38 per cent was soluble in carbon bisulphide. Another sample of asphaltic petroleum from the Gulf Refining Co. flowed at a temperature of 203° F., and carbon bisulphide dissolved 99.88 per cent. Four to six per cent of this material gave excellent results as a binder for briquets. Water-gas tar, which is obtained from illuminating-gas plants, was not tested sufficiently to give satisfactory results. It is necessary, after this material is mixed with the coal, to raise its temperature sufficiently high to liquefy and perhaps even vaporize it.

The water-gas pitch furnished by the Barrett Manufacturing Co. flowed at a temperature of 198° F. Four and one-half to seven per cent of this pitch is equivalent to 6 to 8 per cent of coal-tar pitch, and makes satisfactory briquets. The cost of this binder would be from 45 to 65 cents per ton of briquets.

The wax tailings used in these investigations were obtained from the Standard Oil Co. They melt at about 158° F. Four to six per cent of this material produces good briquets. The quantity of this material produced in the United States is small, and the price is about 6 cents per gallon. This price would make the binding material used in a ton of briquets cost approximately 45 to 60 cents.

Tests made with acid sludge as a binder were not satisfactory. The sludge not only added the unwelcome sulphur, but its binding qualities were inferior.

Asphalt tar was unsatisfactory as a binder, even when 8 to 12 per cent was used, inasmuch as the briquets fell to pieces in the fire. Its use for waterproofing, when starch or other material had been used as a binder, proved fairly satisfactory.

Pintsch-gas tar was obtainable in so small a quantity that only preliminary tests were made covering its use as a binder, and they were only partly satisfactory.

In making coal briquets binding is most successful when the particles of coal are coated and when the void spaces are filled with the binding material. This is best accomplished when the temperature of the mixture, before compression, is raised sufficiently to liquefy or vaporize the binder. The relation between the coal and the binder seems to be physical rather than chemical, though it is possible that certain minor chemical changes may accompany the briquetting operation.

The quantity of the binding material necessary will therefore depend on the aggregate of the surfaces of the coal particles to be coated, on the void spaces to be filled, and on the general physical and chemical character of the coal. Coking coals require less binder than noncoking coals. The percentage of binder necessary for noncoking coals may be diminished and the quality of the briquet improved by the addition of 10 to 20 per cent of coking coal.

Furthermore, when coal is finely pulverized the briquetting is facilitated by the mixture of a considerable percentage of the same or another coal—preferably a nonslacking coal—crushed to sizes ranging from $\frac{1}{16}$ to $\frac{1}{4}$ inch.

The following are mentioned as the more important requisites of a suitable binding material for use in the manufacture of briquets:

(1) It must be inexpensive, on account of the small difference between the prices of slack or fine coal and lump coal.

(2) It should be capable of abundant production in different parts of the country, in order to avoid the necessity of long transportation.

(3) It should be of such character as to make it easily handled and applied at workable temperatures.

(4) It should hold the briquet together, not only during ordinary handling and transportation, but also during protracted exposure to the weather and while burning.

(5) It should not add appreciably to the ash of the coal nor increase the clinker formation in the ash. It should not give off fumes nor seriously increase the smoke in the burning of the briquets. Binding materials that have a low melting or boiling temperature give off more smoke because of the fact that this smoke originates at a temperature too low for complete combustion.

(6) It should increase the heating quality of the coal used in the manufacture of the briquets.

TESTS OF AMERICAN LIGNITE IN GERMANY.

In August, 1904, under the supervision of J. A. Holmes, samples of lignite from Lehigh, N. Dak., and from near Rockdale, Tex., were shipped to Magdeburg and Zeitz, Germany, to determine the feasibility of briquetting these lignites with the German presses. The tests conducted by Dr. Holmes were successful, and the briquets made with these lignites subsequently stood the tests applied to the German lignite briquets, which are extensively used for domestic purposes.

To a part of the briquets made at Magdeburg 2 per cent of ordinary coal-tar pitch was added, with the view of determining what, if any, advantage would result from such an addition. Laboratory tests indicated that the briquets to which this pitch was added burned more rapidly, with more flame, and at a higher heat efficiency than those without it, and the North Dakota lignite seemed to give off fewer sparks in burning. It is estimated that the cost of manufacturing these briquets (not including the cost of the lignite) should not exceed 50 cents per ton. The analyses of the lignite briquets made at Magdeburg are as follows:

Analyses of briquets made at Magdeburg, Germany (lignite dried before briquetting).

	From Lehigh, N. Dak.		From Rockdale, Tex.	
	Without pitch or other binder.	With 2 per cent of pitch added.	Without pitch or other binder.	With 2 per cent of pitch added.
Proximate:				
Moisture	12.96	11.92	8.88	8.92
Volatile matter	37.79	38.68	40.92	41.33
Fixed carbon	38.63	41.11	41.90	42.35
Ash	10.62	8.99	8.30	7.40
Sulphur	.75	1.04	.97	1.07
Ultimate:				
Hydrogen	4.99	5.09	5.21	5.23
Carbon	52.88	56.26	59.06	59.61
Nitrogen	.65	.73	1.15	1.14
Oxygen	30.11	27.89	25.31	25.55
Calories	4,941	5,332	5,682	5,828
British thermal units	8,894	9,598	10,228	10,490
Moisture in undried sample of lignite as received at Magdeburg.	28.87		32.07	

LABORATORY INVESTIGATIONS OF BINDERS AND FUELS.

During the past three years the author has carried on at Pittsburgh laboratory briquetting investigations of certain binding materials, using the hydraulic hand press previously described. As the work progressed, it was found desirable to record data that were not considered essential in the earlier experiments; hence data for the different tests are not alike complete. These laboratory tests should not be confused with the tests made on the large machines. No attempt was made to prepare briquets in sufficient quantity for combustion tests, as the object of the tests was merely to study the briquetting qualities of various fuels and binders.

METHOD OF MAKING LABORATORY BRIQUETTING TESTS.

In making a laboratory test when the mixture was heated by steam, 1,000 grams of a mixture of fuel and binder was prepared, using the proper proportion of the binder. If a solid binder was used, it was first crushed to pass a 20-mesh sieve. If liquid or viscous binders were being tested, they were warmed sufficiently to cause them to mix thoroughly with the coal. The fuel and the binder in either case were mixed by kneading and stirring until a uniform mixture was obtained. Two hundred grams of this mixture was placed in a 2-quart pan and live steam (as dry as possible but not superheated) was blown into the mixture through a ⅛-inch pipe bent at right angles and attached to a flexible rubber hose. This heating was carried on for periods of 20, 30, 60, 90, or 120 seconds, as found advisable from previous experiments with fuels of similar type. After weighing to determine the gain in moisture, the mixture was transferred to the mold of the hydraulic press and the temperature noted. A reading was made on the plunger to determine the length of the mixture before compression. Pressure was then applied and registered on a large gage. When the desired pressure had been obtained, another plunger reading was made, and the difference between this and the reading before compression gave the reduction of volume.

DESIGNATED QUALITIES OF BRIQUETS.

The values of the letters A, B, C, D, or E, used in the tables to designate the quality of fresh briquets and of air-dried briquets, are as follows:

A: An excellent briquet, difficult to fracture with the hands, and having smooth, firm surfaces and sharp, strong edges.

B: A good briquet, lacking some of the qualities mentioned under A, but yet a satisfactory and practical briquet.

C: A fair briquet, somewhat lacking in strength and somewhat rough and soft on the surface and with edges that crumble easily, so that it is hardly a satisfactory briquet.

D: A briquet of poor quality and entirely unsatisfactory, lacking strength, smooth surface, and firm edges.

E: A briquet so poor that it crumbled to pieces when removed from the mold.

The abbreviation "S. J." in the table under the item "Method of Heating" indicates the use of a steam jet. The letters W. G. P. represent water-gas pitch.

COMPRESSION TEST.

As a measure of the strength, the compressive strength or the amount of pressure the laboratory briquets would stand without breaking was more closely comparable than that noted in briquets made on the larger presses.

DETAILS OF LABORATORY BINDER TESTS.

In the following table are given the physical and chemical characteristics of the binders used in the laboratory tests:

Binders used in laboratory briquetting tests.

Lot No.	Laboratory No.	Kind of binder.	Extracted by carbon bisulphide.	Heat value.	Flowing point.	Proximate analysis.				
						Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.
			Per ct.	*B. t. u.*	°*F.*					
26	5940	Water-gas pitch....	96.60	16,780	178	....				....
27	9298	Cell pitch..........	....	6,550	(*a*)	8.10	57.79	9.09	25.04	2.21
29	11990	Hardwood-tar pitch	....	14,233	82	1.20	78.87	19.67	.26	.14
31	14768	Wheat flour........	....	6,856	....	13.83	78.18	7.99	.0	.12
32	12515	Sulphite liquor.....	....	4,586	....	39.16	43.04	8.69	9.11	3.13
34	14769	.....do.............	....	4,734	....	37.98	38.59	13.52	9.91	3.06

[a] Burned to ash without melting.

TESTS WITH PITTSBURGH NO. 15.[a]

The data obtained from laboratory tests of Pittsburgh No. 15 and various binders are given in the following tables:

Laboratory briquetting tests of Pittsburgh No. 15 without binder.

	Test No.						
	L 158.	L 169A.	L 169B.	L 169C.	L 169D.	L 169E.	L 169F.
Size as used:							
Over ¼ inch, per cent........	0.8	0.8	0.8	0.8	0.8	0.8	0.8
$\frac{1}{10}$ to ¼ inch, per cent........	45.3	45.3	45.3	45.3	45.3	45.3	....
$\frac{1}{20}$ to $\frac{1}{10}$ inch, per cent........	32.4	32.4	32.4	32.4	32.4	32.4	....
$\frac{1}{40}$ to $\frac{1}{20}$ inch, per cent........	11.7	11.7	11.7	11.7	11.7	11.7	....
Through $\frac{1}{40}$ inch, per cent...	9.8	9.8	9.8	9.8	9.8	9.8	9.8
Briquetting temperature, °F....	Warm.	Cold.	182	178	192	Cold.	Cold.
Binder, amount used, per cent..	None.	None.	None.	None.	None.	None.	None.
Method of heating used..........	S. J.	Cold.	S. J.	S. J.	S. J.	....	....
Weight of:							
Mixture used, grams........	200	200	200	100	200	100	100
Briquet, average, grams....	200	200	205	....	....	100	100
Condition of fuel, dried or undried..........................	Undried.	Dried.	Dried.	Dried.	Dried.	Dried.	Dried.
Pressure used, pounds per square inch..................	14,000	14,000	14,000	30,000	6,000	30,000	20,000
Moisture:							
In fuel, per cent.............	30.7	10.0	10.0	10.0	10.0	10.0	10.0
Added in heating, per cent..	....	....	4.0	3.0	5.0	0	0
In briquet, per cent.........	....	....	14.0	13.0	15.0	10.0	10.0
Length of heating, minutes.....	....	....	½	½	½	....	....
Reduction of volume by press-square inch..................	....	....	46	....	....	....	....
Quality of briquet:							
Fresh[b]......................	E	D	D	D	E	D+	D+
Air-dried[b]...................	....	D	D	D	E	D+	D+

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[a] See table, p. 39.

[b] See p. 71 for value of letters.

Laboratory briquetting tests of Pittsburgh No. 15 with water-gas pitch binder.

	Test No.					
	L 160.	L 161.	L 162.	L 170.	L 171.	L 172.
Size as used:						
Over ¼ inch, per cent	0.8	0.8	0.8	0.8	0.8	0.8
$\frac{1}{10}$ to ¼ inch, per cent	45.3	45.3	45.3	45.3	45.3	45.3
$\frac{1}{20}$ to $\frac{1}{10}$ inch, per cent	32.4	32.4	32.4	32.4	32.4	32.4
$\frac{1}{40}$ to $\frac{1}{20}$ inch, per cent	11.7	11.7	11.7	11.7	11.7	11.7
Through $\frac{1}{40}$ inch, per cent	9.8	9.8	9.8	9.8	9.8	9.8
Briquetting temperature, °F	156	156	172	186	177	175
Binder:						
Lot No	26	26	26	26	26	26
Amount used, per cent	4	6	8	4	6	8
Method of heating used	S. J.	S. J.	S. J.	S. J.	S. J.	S. J.
Weight of:						
Mixture used, grams	200	200	200	200	200	200
Briquet, average, grams	207	207	208	208	207	208
Condition of fuel, dried or undried	Undried.	Undried.	Undried.	Dried.	Dried.	Dried.
Pressure used, pounds per square inch	6,000	6,000	6,000	6,000	6,000	6,000
Moisture:						
In fuel, per cent	30.7	30.7	30.7	10.0	10.0	10.0
Added in heating, per cent	5.5	5.5	6.0	4.5	4.0	4.5
In briquet, per cent	36.2	36.2	36.7	14.5	14.0	14.5
Length of heating, minutes	½	½	½	½	½	½
Reduction of volume by pressing, per cent	45	45	45	46	46	46
Crushing strength, pounds per square inch	200	200	200	200	300	650
Quality of briquet:						
Fresh	D	D	D	D	D	C
Air-dried	D	D	D	D	C	B

Laboratory briquetting tests of Pittsburgh No. 15 with wheat-flour binder.

	Test No.					
	L 166.	L 167.	L 168.	L 176.	L 177.	L 178.
Size as used:						
Over ¼ inch, per cent	0.8	0.8	0.8	0.8	0.8	0.8
$\frac{1}{10}$ to ¼ inch, per cent	45.3	45.3	45.3	45.3	45.3	45.3
$\frac{1}{20}$ to $\frac{1}{10}$ inch, per cent	32.4	32.4	32.4	32.4	32.4	32.4
$\frac{1}{40}$ to $\frac{1}{20}$ inch, per cent	11.7	11.7	11.7	11.7	11.7	11.7
Through $\frac{1}{40}$ inch, per cent	8.8	8.8	8.8	8.8	8.8	8.8
Briquetting temperature, °F	196	191	181	190	194	183
Binder:						
Lot No	31	31	31	31	31	31
Amount used, per cent	3	5	7	3	5	7
Method of heating used	S. J.	S. J.	S. J.	S. J.	S. J.	S. J.
Weight of:						
Mixture used, grams	200	200	200	200	200	200
Briquet, average, grams	208	211	210	210	211	211
Condition of fuel, dried or undried	Undried.	Undried.	Undried.	Dried.	Dried.	Dried.
Pressure used, pounds per square inch	6,000	6,000	6,000	6,000	6,000	6,000
Moisture:						
In fuel, per cent	30.7	30.7	30.7	10.0	10.0	10.0
Added in heating, per cent	7.0	7.5	7.5	5.5	7.0	6.5
In briquet, per cent	37.7	38.2	38.2	15.5	17.0	16.5
Length of heating, minutes	1	1	1	1	1	1
Reduction of volume by pressing, per cent	42	43	40	46	46	46
Crushing strength, pounds per square inch	600	1,000	1,125	750	1,150	1,100
Quality of briquet:						
Fresh	C	A	A	B	A	[a]A
Air-dried	B	A	A	B	A	[a]A

[a] Edges brittle.

Laboratory briquetting tests of Pittsburgh No. 15 with cell-pitch binder.

	Test No.				
	L 163.	L 164.	L 165.	L 174.	L 175.
Size as used:					
Over ¼ inch, per cent	0.8	0.8	0.8	0.8	0.8
$\frac{1}{10}$ to ¼ inch, per cent	45.3	45.3	45.3	45.3	45.3
$\frac{1}{20}$ to $\frac{1}{10}$ inch, per cent	32.4	32.4	32.4	32.4	32.4
$\frac{1}{40}$ to $\frac{1}{20}$ inch, per cent	11.7	11.7	11.7	11.7	11.7
Through $\frac{1}{40}$ inch, per cent	9.8	9.8	9.8	9.8	9.8
Briquetting temperature, °F	169	167	173	163	174
Binder:					
Lot No.	27	27	27	27	27
Amount used, per cent	4	6	8	6	8
Method of heating used	S. J.	S. J.	S. J.	S. J.	S. J.
Weight of:					
Mixture used, grams	200	200	200	200	200
Briquet, average, grams	209	207	207	206	208
Condition of fuel, dried or undried	Undried.	Undried.	Undried.	Dried.	Dried.
Pressure used, pounds per square inch	6,000	6,000	6,000	6,000	6,000
Moisture:					
In fuel, per cent	30.7	30.7	30.7	10.0	10.0
Added in heating, per cent	6.0	5.5	6.0	4.0	5.0
In briquet, per cent	36.7	36.2	36.7	14.0	15.0
Length of heating, minutes	½	½	½	½	½
Reduction of volume by pressing, per cent	43	43	45	50	50
Crushing strength, pounds per square inch	200	200	....	550	925
Quality of briquet:					
Fresh	D	D	D	C	B
Air-dried	D	C	C	C	B

The results obtained from these experiments show that North Dakota lignite (Pittsburgh No. 15) can not be successfully briquetted without binder, even under high pressure. The briquets made from the undried fuel with 8 per cent of the water-gas pitch were not satisfactory. When the fuel was dried to contain only 10 per cent of moisture, and 8 per cent of the water-gas pitch was used, a satisfactory briquet was obtained. With 3 to 5 per cent of flour as a binder excellent briquets were obtained from both the dried and the undried fuel, although they would not be waterproof and would have to be stored under cover.

With 8 per cent of cell pitch the dried fuel made a satisfactory briquet. Of course briquets made with this binder would not be waterproof and would have to be stored under cover. The source and analysis of this fuel are given under "Details of Briquetting Tests."

TESTS WITH PITTSBURGH NO. 17.[a]

The data obtained from laboratory tests of Pittsburgh No. 17 and various binding materials are given in the following tables:

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[a] See table, p. 39.

Laboratory briquetting tests of Pittsburgh No. 17 without binder.

	Test No.						
	L 225.	L 226.	L 227.	L 228.	L 237.	L 238.	L 239.
Size as used:							
Over $\frac{1}{4}$ inch, per cent	9.7	9.7	9.7	9.7	9.7	9.7	9.7
$\frac{1}{10}$ to $\frac{1}{4}$ inch, per cent	40.5	40.5	40.5	40.5	40.5	40.5	40.5
$\frac{1}{20}$ to $\frac{1}{10}$ inch, per cent	26.5	26.5	26.5	26.5	26.5	26.5	26.5
$\frac{1}{40}$ to $\frac{1}{20}$ inch, per cent	12.7	12.7	12.7	12.7	12.7	12.7	12.7
Through $\frac{1}{40}$ inch, per cent	10.6	10.6	10.6	10.6	10.6	10.6	10.6
Briquetting temperature, °F	Cold.	Cold.	Cold.	157	189	194	187
Binder, amount used, per cent	None.	None.	None.	None.	None.	None.	None.
Method of heating used	Cold.	Cold.	Cold.	([a])	S. J.	S. J.	([a])
Weight of:							
Mixture used, grams	200	200	155	150	200	150	150
Briquet, average, grams	199	200	155	146	202	157	149
Condition of fuel, dried or undried	Undried.	Undried.	Undried.	Undried.	Dried.	Dried.	Dried.
Pressure used, pounds per square inch	14,000	6,000	32,000	32,000	14,000	32,000	32,000
Moisture:							
In fuel, per cent	31.6	31.6	31.6	31.6	14.1	14.1	14.1
Added in heating, per cent	....	....	....	−1.5	3.5	4.5	0
In briquet, per cent	31.6	31.6	31.6	30.1	17.6	18.6	14.1
Length of heating, minutes	Cold.	Cold.	Cold.	([b])	$\frac{1}{2}$	1	([b])
Reduction of volume by pressing, per cent	50	48	....	....	43	....	....
Crushing strength, pounds per square inch	....	....	....	....	....	200	....
Quality of briquet:							
Fresh	D	D	D	E	C	D.	C
Air-dried	D	D	D	....	C	D.	C

[a] Gas flame. [b] Until hot.

Laboratory briquetting tests of Pittsburgh No. 17 with water-gas pitch binder.

	Test No.					
	L 199.	L 200.	L 201.	L 202.	L 203.	L 229.
Size as used:						
Over $\frac{1}{4}$ inch, per cent	9.7	9.7	9.7	9.7	9.7	9.7
$\frac{1}{10}$ to $\frac{1}{4}$ inch, per cent	40.5	40.5	40.5	40.5	40.5	40.5
$\frac{1}{20}$ to $\frac{1}{10}$ inch, per cent	26.5	26.5	26.5	26.5	26.5	26.5
$\frac{1}{40}$ to $\frac{1}{20}$ inch, per cent	12.7	12.7	12.7	12.7	12.7	12.7
Through $\frac{1}{40}$ inch, per cent	10.6	10.6	10.6	10.6	10.6	10.6
Briquetting temperature, °F	201	201	199	198	198	187
Binder:						
Lot No.	26	26	26	26	26	26
Amount used, per cent	4	5	6	7	8	6
Method of heating used	S. J.	S. J.	S. J.	S. J.	S. J.	S. J.
Weight of:						
Mixture used, grams	200	200	200	200	200	200
Briquet, average, grams	209	209	209	209	210	207
Condition of fuel, dried or undried	Undried.	Undried.	Undried.	Undried.	Undried.	Dried.
Pressure used, pounds per square inch	4,000	4,000	4,000	4,000	4,000	4,000
Moisture:						
In fuel, per cent	31.6	31.6	31.6	31.6	31.6	15.7
Added in heating, per cent	6.5	7.0	6.5	5.5	6.5	4.5
In briquet, per cent	38.1	38.6	38.1	37.1	38.1	20.2
Length of heating, minutes	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
Reduction of volume by pressing, per cent	47	47	46	46	46	49
Crushing strength, pounds per square inch	−300	−300	−300	[a] −300	350	400
Quality of briquet:						
Fresh	D	D	D	D	D	C
Air-dried	D	D	D	D	C	C

[a] Indicates that strength was less than 300 pounds per square inch, the lowest pressure that the gage would register.

Laboratory briquetting tests of Pittsburgh No. 17 with flour binder.

	Test No.							
	L 204.	L 205.	L 206.	L 207.	L 208.	L 209.	L 210.	L 230.
Size as used:								
Over 1/4 inch, per cent	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7
1/10 to 1/4 inch, per cent	40.5	40.5	40.5	40.5	40.5	40.5	40.5	40.5
1/20 to 1/10 inch, per cent	26.5	26.5	26.5	26.5	26.5	26.5	26.5	26.5
1/40 to 1/20 inch, per cent	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7
Through 1/40 inch, per cent	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6
Briquetting temperature, °F	201	201	203	201	201	192	201	199
Binder:								
Lot No	31	31	31	31	31	31	31	31
Amount of, per cent	2	3	4	5	6	7	8	6
Method of heating used	S. J.	S. J.	S. J.	S. J.	S. J.	S. J.	S. J.	S. J.
Weight of:								
Mixture used, grams	200	200	200	200	200	200	200	200
Briquet, average, grams	211	210	211	210	211	210	210	209
Condition of fuel, dried or undried	Undried.	Undried.	Undried.	Undried.	Undried.	Undried.	Undried.	Dried.
Pressure used, pounds per square inch	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
Moisture:								
In fuel, per cent	31.6	31.6	31.6	31.6	31.6	31.6	31.6	15.7
Added in heating, per cent	7.5	7.0	7.5	7.0	7.5	7.0	7.0	6.0
In briquet mixture, per cent	39.1	38.6	39.1	38.6	39.1	38.6	38.6	21.7
Length of heating, minutes	1	1	1	1	1	1	1	1
Reduction of volume by pressing, per cent	45	45	45	45	45	46	45	44
Crushing strength, pounds per square inch	600	750	1,100	1,125	1,200	1,075	1,525	1,000
Quality of briquet:								
Fresh	D	C	D	B	A	B	A	B
Air-dried	C	B	B	A	A	B	A	B

Laboratory briquetting tests of Pittsburgh No. 17 with sulphite-liquor binder.

	Test No.							
	L 218.	L 219.	L 220.	L 221.	L 222.	L 223.	L 224.	L 231.
Size as used:								
Over $\frac{1}{4}$ inch, per cent	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7
$\frac{1}{10}$ to $\frac{1}{4}$ inch, per cent	40.5	40.5	40.5	40.5	40.5	40.5	40.5	40.5
$\frac{1}{20}$ to $\frac{1}{10}$ inch, per cent	26.5	26.5	26.5	26.5	26.5	26.5	26.5	26.5
$\frac{1}{40}$ to $\frac{1}{20}$ inch, per cent	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7
Through $\frac{1}{40}$ inch, per cent	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6
Briquetting temperature, °F	199	197	201	201	196	196	198	....
Binder:								
Lot No	32	32	32	32	32	32	32	32
Amount used, per cent	3	4	5	6	7	8	9	6
Method of heating used	S. J.	S. J.	S. J.	S. J.	S. J.	S. J.	S. J.	S. J.
Weight of:								
Mixture used, grams	200	200	200	200	200	200	200	200
Briquet, average, grams	210	209	209	210	208	209	208	207
Condition of fuel, dried or undried	Undried.	Undried.	Undried.	Undried.	Undried.	Undried.	Undried.	Dried.
Pressure used, pounds per square inch	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
Moisture:								
In fuel, per cent	31.6	31.6	31.6	31.6	31.6	31.6	31.6	15.7
Added in heating, per cent	6.0	6.0	6.0	6.5	5.5	6.0	6.5	5.0
In briquet mixture, per cent	37.6	37.6	37.6	38.1	37.1	37.6	38.1	20.7
Length of heating, minutes	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
Reduction of volume by pressing, per cent	45	46	46	46	46	46	46	43
Crushing strength, pounds per square inch	....	....	....	....	....	....	....	450
Quality of briquet:								
Fresh	E	E	E	D	D	D	D	D
Air-dried	E	E	E	D	D	D	D	C

The North Dakota lignite represented by Pittsburgh No. 17 can be briquetted without binder by pressure alone if partly dried and heated with steam before pressing. The dried fuel that was briquetted without binder contained 14.1 per cent of moisture. The undried fuel was not satisfactorily briquetted without binder.

With 6 per cent of water-gas pitch better briquets could be made from the dried than from the undried fuel, whereas 8 per cent did not produce as good results with the undried fuel.

Four per cent of flour binder was required to make satisfactory briquets of this fuel in an undried condition, and 6 per cent of flour was sufficient to make excellent briquets with the undried fuel.

Nine per cent of sulphite liquor (lot No. 32) was insufficient to make fair briquets from this undried fuel, but 6 per cent made good briquets when the dried fuel contained 15.7 per cent of moisture.

The sample had the following analysis:

Proximate analysis (as received).

		Per cent.
Moisture		31.99
Volatile matter		31.70
Fixed carbon		31.27
Ash		5.04
Sulphur		.46
Heating value	B. t. u.	7,353

TESTS WITH PENNSYLVANIA ANTHRACITE CULM.

The data obtained from laboratory tests of Pennsylvania anthracite culm (Pennsylvania No. 3 [a]) and various binders are given in the following table:

Laboratory briquetting tests of Pennsylvania culm with cell-pitch binder.

	Test No.	
	L 80.	L 81.
Briquetting temperature, °F	176	203
Binder:		
Lot No	27	27
Amount used, per cent	3	3
Method of heating used	Gas flame.	S. J.
Weight of:		
Mixture used, grams	212	200
Briquet, average, grams	203	....
Condition of fuel, dried or undried	Undried.	Undried.
Pressure used, pounds per square inch	4,000	4,000
Moisture added in heating, per cent	4.5	....
Length of heating, minutes	....	½
Reduction of volume by pressing, per cent	46	44
Crushing strength, pounds per square inch	2,700	....
Quality of briquet:		
Fresh	B	E
Air-dried	A	....

Laboratory briquetting tests of Pennsylvania culm with sulphite-liquor binder.

	Test No.					
	L 77A.	L 77B.	L 77C.	L 78.	L 82.	L 83.
Briquetting temperature, ° F	Cold.	201	180	158	Cold.	Hot.
Binder:						
Lot No	34	34	34	34	34	34
Amount used, per cent	10	5	1	4.3	5	5
Method of heating used	Cold.	Gas flame.	Gas flame.	Heated in mold.	Cold.	Steam jet.
Weight of:						
Mixture used, grams	200	200	200	200	200	200
Briquet, average, grams	200	200	200	200	200	200
Condition of fuel, dried or undried	Undried.	Undried.	Undried.	Undried.	Undried.	Undried.
Pressure used, pounds per square inch	4,000	4,000	4,000	4,000	6,000	6,000
Length of heating, minutes	Cold.	Until warm.	Until warm.	....	....	½
Reduction of volume by pressing, per cent	40	40	40	44	....	42
Crushing strength, pounds per square inch	2,600	2,500	....	....	....	....
Quality of briquet:						
Fresh	D	B	E	C	C	E
Air-dried	A	A	E	B	B	E

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[a] See table, p. 40.

Laboratory briquetting tests of Pennsylvania culm with sulphite-liquor binder—Continued.

	Test No.		
	L 85.	L 84.	L 86.[a]
Briquetting temperature, °F	Hot.	176	Cold.
Binder:			
Lot No	34	34	34
Amount used, per cent	5	5	5
Method of heating used	Oven.	Gas flame.	Cold.
Weight of:			
Mixture used, grams	200	200	200
Briquet, average, grams	200	97.5	200
Condition of fuel, dried or undried	Dried.	Dried.	....
Pressure used, pounds per square inch	10,000	6,000	6,000
Moisture removed in heating, per cent	....	2½	....
Length of heating, minutes	15	....	Hot molds
Reduction of volume by pressing, per cent	....	48	40
Crushing strength, pounds per square inch	....	....	2,800
Quality of briquet:			
Fresh	C	C	C
Air-dried	A	B	A

[a] Test 86 was made with a mixture of 50 per cent each of Pittsburgh slack and anthracite culm.

A sample of Pennsylvania anthracite culm and 3 per cent of cell pitch made strong briquets. However, better results were obtained by heating the mixture with a gas flame before pressing than when a steam jet was used.

With 10 per cent of sulphite liquor pressed cold, the briquet was very soft while fresh and had hardly strength enough to stand conveyance to storage. With 5 per cent of sulphite liquor heated over a gas flame before pressing, excellent briquets were obtained.

TESTS WITH PHILIPPINE LIGNITE.

The data obtained from laboratory tests of Philippine lignite (Pittsburgh No. 112[a]) and various binders are given in the following tables:

Laboratory briquetting tests of Philippine lignite without binder.

	Test No.				
	L 97.	L 98.	L 117.	L 118.	L 119.
Size as used:					
Over ¼ inch, per cent	8.3	8.3	0.0	0.0	1.0
$\frac{1}{10}$ to ¼ inch, per cent	50.3	50.3	0.0	0.0	14.0
$\frac{1}{20}$ to $\frac{1}{10}$ inch, per cent	24.8	24.8	0.0	0.0	30.0
$\frac{1}{40}$ to $\frac{1}{20}$ inch, per cent	9.6	9.6	0.0	0.0	27.7
Through $\frac{1}{40}$ inch, per cent	7.0	7.0	100.0	100.0	27.3
Briquetting temperature, °F	Hot.	Hot.	(b)	(b)	(b)
Binder, amount used, per cent	None.	None.	None.	None.	None.
Method of heating used	S. J.	S. J.	S. J.	S. J.	S. J.
Weight of:					
Mixture used, grams	(b)	180	200	150	150
Briquet, average, grams	(c)	(c)	(c)	(c)	(c)
Condition of fuel, dried or undried	Undried.	Dried.	Dried.	Dried.	Undried.
Pressure used, pounds per square inch	14,000	14,000	14,000	30,000	30,000
Moisture in fuel, per cent	20.0	6.0	10.0	10.0	20.0
Moisture added in heating, per cent	(b)	(b)	(b)	(b)	(b)
Moisture in briquet, per cent	(b)	(b)	(b)	(b)	(b)
Length of heating, minutes	¾	½	2	2	2
Reduction of volume by pressing, per cent	45	44.2	(b)	(b)	(b)
Quality of briquet:					
Fresh	E	E	E	E	E
Air-dried	E	E	E	E	E

[a] See table, p. 140.

[b] Not determined.

[c] None made.

Laboratory briquetting tests of Philippine lignite with water-gas pitch binder.

	Test No.					
	L 96.	L 95.	L 99.	L 100.	L 101.	L 102.
Size as used:						
Over ¼ inch, per cent	8.3	8.3	0.0	0.0	1.0	1.0
1/10 to ¼ inch, per cent	50.3	50.3	54.8	54.8	14.0	14.0
1/20 to 1/10 inch, per cent	24.8	24.8	27.0	27.0	30.0	30.0
1/40 to 1/20 inch, per cent	9.6	9.6	10.6	10.6	27.7	27.7
Through 1/40 inch, per cent	7.0	7.0	7.6	7.6	27.3	27.3
Briquetting temperature, °F	163	136	131	147	142	145
Binder:						
Lot No	26	26	26	26	26	26
Amount used, per cent	4	6	8	4	6	8
Method of heating used	S. J.	S. J.	S. J.	S. J.	S. J.	S. J.
Weight of:						
Mixture used, grams	200	200	200	200	200	200
Briquet, average, grams	206	205	203	209	208	208
Condition of fuel, dried or undried	Undried.	Undried.	Undried.	Dried.	Dried.	Dried.
Pressure used, pounds per square inch	6,000	6,000	6,000	6,000	6,000	6,000
Moisture:						
In fuel, per cent	20.0	20.0	20.0	5.0	5.0	5.0
Added in heating, per cent	6.9	4.6	4.5	5.0	4.5	4.5
In briquet, per cent	26.9	24.6	24.5	10.0	9.5	9.5
Length of heating, minutes	¾	¾	¾	¾	¾	¾
Reduction of volume by pressing, per cent	43.3	39.7	40.7	39.4	43.0	41.0
Crushing strength, pounds per square inch	950	1,400	1,675	625	1,050	1,550
Quality of briquet:						
Fresh	C	B	A	D	B	A
Air-dried	B	A	A	C	A	A

Laboratory briquetting tests of Philippine lignite with wheat-flour binder.

	Test No.					
	L 144.	L 156.	L 115.	L 157.	L 184.	L 146.
Size as used:						
Over ¼ inch, per cent	0.0	0.0	1.0	0.0	0.0	0.0
1/10 to ¼ inch, per cent	14.1	14.1	14.0	14.1	14.1	14.1
1/20 to 1/10 inch, per cent	30.6	30.6	30.0	30.6	30.6	30.6
1/40 to 1/20 inch, per cent	28.0	28.0	27.7	28.0	28.0	28.0
Through 1/40 inch, per cent	27.3	27.3	27.3	27.3	27.3	27.3
Briquetting temperature, °F	191	193	138	192	172	197
Binder:						
Lot No	31	31	31	31	31	31
Amount used, per cent	4	5	6	6	6	8
Method of heating used	S. J.	S. J.	S. J.	S. J.	S. J.	S. J.
Weight of:						
Mixture used, grams	200	200	200	200	200	200
Briquet, average, grams	210	211	210	210	210	209
Condition of fuel, dried or undried	Undried.	Undried.	Undried.	Undried.	Undried.	Undried.
Pressure used, pounds per square inch	6,000	6,000	6,000	6,000	6,000	6,000
Moisture:						
In fuel, per cent	20.0	20.0	20.0	20.0	20.0	20.0
Added in heating, per cent	7.5	7.0	8.0	7.0	6.0	6.5
In briquet, per cent	27.5	27.0	28.0	27.0	26.0	26.5
Length of heating, minutes	1½	1	2	1	1	1
Reduction of volume by pressing, per cent	44.5	44.6	46.1	44.6	45.0	43.6
Crushing strength, pounds per square inch	1,550	1,400	1,550	1,425	1,200	1,975
Quality of briquet:						
Fresh	B	B	B	B	A	A
Air-dried	A	A	[a] A	B	A	A

[a] Water cracks due to too much heating.

Laboratory briquetting tests of Philippine lignite with wheat-flour binder—Continued.

	Test No.		
	L 111.	L 112.	L 113.
Size as used:			
Over ¼ inch, per cent	1.0	1.0	1.0
$\frac{1}{10}$ to ¼ inch, per cent	14.0	14.0	14.0
$\frac{1}{20}$ to $\frac{1}{10}$ inch, per cent	30.0	30.0	30.0
$\frac{1}{40}$ to $\frac{1}{20}$ inch, per cent	27.7	27.7	27.7
Through $\frac{1}{40}$ inch, per cent	27.3	27.3	27.3
Briquetting temperature, °F	145	149	153
Binder:			
Lot No	31	31	31
Amount used, per cent	4	6	8
Method of heating used	S. J.	S. J.	S. J.
Weight of:			
Mixture used, grams	200	200	200
Briquet, average, grams	204	205	204
Condition of fuel, dried or undried	Dried.	Dried.	Dried.
Pressure used, pounds per square inch	6,000	6,000	6,000
Moisture:			
In fuel, per cent	5.0	5.0	5.0
Added in heating, per cent	4.5	4.5	4.5
In briquet, per cent	9.5	9.5	9.5
Length of heating, minutes	1½	1½	1½
Reduction of volume by pressing, per cent	44.8	43.1	44.6
Crushing strength, pounds per square inch	0.0	0.0	0.0
Quality of briquet:			
Fresh	E	E	E
Air-dried	E	E	E

Laboratory briquetting tests of Philippine lignite with cornstarch binder.

	Test No.					
	L 138.	L 139.	L 103.	L 104.	L 105.	L 106.
Size as used:						
Over ¼ inch, per cent	1.0	1.0	1.0	1.0	1.0	1.0
$\frac{1}{10}$ to ¼ inch, per cent	14.0	14.0	14.0	14.0	14.0	14.0
$\frac{1}{20}$ to $\frac{1}{10}$ inch, per cent	30.0	30.0	30.0	30.0	30.0	30.0
$\frac{1}{40}$ to $\frac{1}{20}$ inch, per cent	27.7	27.7	27.7	27.7	27.7	27.7
Through $\frac{1}{40}$ inch, per cent	27.3	27.3	27.3	27.3	27.3	27.3
Briquetting temperature, °F	181	156	147	149	149	149
Binder:						
Lot No	35	35	35	35	35	35
Amount used, per cent	3	5	3	5	6	7
Method of heating used	S. J.	S. J.	S. J.	S. J.	S. J.	S. J.
Weight of:						
Mixture used, grams	200	200	200	200	200	200
Briquet, average, grams	210	205	203	204	202	201
Condition of fuel, dried or undried	Undried.	Undried.	Dried.	Dried.	Dried.	Dried.
Pressure used, pounds per square inch	6,000	6,000	6,000	6,000	6,000	6,000
Moisture:						
In fuel, per cent	20.0	20.0	5.0	5.0	5.0	5.0
Added in heating, per cent	7.0	3.5	4.5	4.5	3.5	2.5
In briquet, per cent	27.0	23.5	9.5	9.5	8.5	7.5
Length of heating, minutes	2	½	¾	1½	1½	1½
Reduction of volume by pressing, per cent	45.3	44.6	38.5	37.0	38.5	35.5
Crushing strength, pounds per square inch	1,150	1,225	0.0	0.0	0.0	0.0
Quality of briquet:						
Fresh	D	C	D	D	D	D
Air-dried	B	B	D	[a] D	[a] D	[a] D

[a] Briquets were too dry.

Laboratory briquetting tests of Philippine lignite with cell-pitch binder.

	Test No.					
	L 140.	L 143.	L 142.	L 141.	L 107.	L 108.
Size as used:						
Over ¼ inch, per cent	1.0	1.0	1.0	1.0	1.0	1.0
$\frac{1}{10}$ to ¼ inch, per cent	14.0	14.0	14.0	14.0	14.0	14.0
$\frac{1}{20}$ to $\frac{1}{10}$ inch, per cent	30.0	30.0	30.0	30.0	30.0	30.0
$\frac{1}{40}$ to $\frac{1}{20}$ inch, per cent	27.7	27.7	27.7	27.7	27.7	27.7
Through $\frac{1}{40}$ inch, per cent	27.3	27.3	27.3	27.3	27.3	27.3
Briquetting temperature, °F	148	180	167	152	147	135
Binder:						
Lot No.	27	27	27	27	27	27
Amount used, per cent	4	5	6	7	4	5
Method of heating used	S. J.	S. J.	S. J.	S. J.	S. J.	S. J.
Weight of:						
Mixture used, grams	200	200	200	200	200	200
Briquet, average, grams	204	207	206	205	209	210
Condition of fuel, dried or undried	Undried.	Undried.	Undried.	Undried.	Dried.	Dried.
Pressure used, pounds per square inch	6,000	6,000	6,000	6,000	6,000	6,000
Moisture:						
In fuel, per cent	20.3	20.3	20.3	20.3	5.0	5.0
Added in heating, per cent	3.5	4.5	4.5	4.0	5.5	6.0
In briquet, per cent	23.8	24.8	24.8	24.3	10.5	11.0
Length of heating, minutes	½	½	½	½	1½	1½
Reduction of volume by pressing, per cent	40.0	41.6	41.6	41.6	42.8	41.5
Crushing strength, pounds per square inch	800	900	925	950	475	450
Quality of briquet:						
Fresh	D	D	D	C	D	D
Air-dried	C	C	B	B	D	D

	Test No.			
	L 109.	L 145.	L 110.	L 147.
Size as used:				
Over ¼ inch, per cent	1.0	0.0	1.0	0.0
$\frac{1}{10}$ to ¼ inch, per cent	14.0	14.1	14.0	14.1
$\frac{1}{20}$ to $\frac{1}{10}$ inch, per cent	30.0	30.6	30.0	30.6
$\frac{1}{40}$ to $\frac{1}{20}$ inch, per cent	27.7	28.0	27.7	28.0
Through $\frac{1}{40}$ inch, per cent	27.3	27.3	27.3	27.3
Briquetting temperature, °F	131	176	138	198
Binder:				
Lot No.	27	27	27	27
Amount used, per cent	6	6	7	6
Method of heating used	S. J.	S. J.	S. J.	S. J.
Weight of:				
Mixture used, grams	200	200	200	200
Briquet, average, grams	210	207	209	208
Condition of fuel, dried or undried	Dried.	Dried.	Dried.	Dried.
Pressure used, pounds per square inch	6,000	6,000	6,000	6,000
Moisture:				
In fuel, per cent	5.0	10.0	5.0	15.0
Added in heating, per cent	6.0	4.5	6.0	5.5
In briquet, per cent	11.0	14.5	11.0	20.5
Length of heating, minutes	1½	½	1½	½
Reduction of volume by pressing, per cent	42.9	41.5	42.6	44.6
Crushing strength, pounds per square inch	575	775	775	950
Quality of briquet:				
Fresh	D	C	C	C
Air-dried	C	B	C	B

Laboratory briquetting tests of Philippine lignite with sulphite-liquor binder.

	Test No.					
	L 148.	L 149.	L 150.	L 151.	L 116.	L 152.
Size as used:						
Over $\frac{1}{4}$ inch, per cent	0.0	0.0	0.0	0.0	1.0	1.0
$\frac{1}{10}$ to $\frac{1}{4}$ inch, per cent	14.1	14.1	14.1	14.1	14.1	14.1
$\frac{1}{20}$ to $\frac{1}{10}$ inch, per cent	30.6	30.6	30.6	30.6	30.0	30.6
$\frac{1}{40}$ to $\frac{1}{20}$ inch, per cent	28.0	28.0	28.0	28.0	27.7	27.7
Through $\frac{1}{40}$ inch, per cent	27.3	27.3	27.3	27.3	27.3	27.3
Briquetting temperature, °F	211	212	210	211	218	208
Binder:						
Lot No	34	34	34	34	34	34
Amount used, per cent	4	5	6	7	4	4
Method of heating used	S. J.	S. J.	S. J.	S. J.	S. J.	S. J.
Weight of:						
Mixture used, grams	200	200	200	200	200	200
Briquet, average, grams	207	208	208	208	216	206
Condition of fuel, dried or undried	Undried.	Undried.	Undried.	Undried.	Dried.	Dried.
Pressure used, pounds per square inch	6,000	6,000	6,000	6,000	6,000	6,000
Moisture:						
In fuel, per cent	20.3	20.3	20.3	20.3	5.0	7.1
Added in heating, per cent	5.5	6.0	5.0	5.5	9.0	4.0
In briquet, per cent	25.8	26.3	25.3	25.8	14.0	11.1
Length of heating, minutes	½	½	½	½	1½	½
Reduction of volume by pressing, per cent	36.4	41.6	40.0	40.0	42.0	35.0
Crushing strength, pounds per square inch	725	775	600	625	450	500
Quality of briquet:						
Fresh	D	D	D	C	D	D
Air-dried	C	C	C	C	C	C

	Test No.		
	L 153.	L 154.	L 155.
Size as used:			
Over $\frac{1}{4}$ inch, per cent	1.0	1.0	1.0
$\frac{1}{10}$ to $\frac{1}{4}$ inch, per cent	14.0	14.0	14.0
$\frac{1}{20}$ to $\frac{1}{10}$ inch, per cent	30.0	30.0	30.0
$\frac{1}{40}$ to $\frac{1}{20}$ inch, per cent	27.7	27.7	27.7
Through $\frac{1}{40}$ inch, per cent	27.3	27.3	27.3
Briquetting temperature, °F	209	211	210
Binder:			
Lot No	34	34	34
Amount used, per cent	5	8	7
Method of heating used	S. J.	S. J.	S. J.
Weight of:			
Mixture used, grams	200	200	200
Briquet, average, grams	207	209	209
Condition of fuel, dried or undried	Dried.	Dried.	Dried.
Pressure used, pounds per square inch	6,000	6,000	6,000
Moisture:			
In fuel, per cent	7.1	7.1	7.1
Added in heating, per cent	4.5	5.5	5.0
In briquet, per cent	11.6	12.6	12.1
Length of heating, minutes	½	½	½
Reduction of volume by pressing, per cent	36.5	40.0	43.1
Crushing strength, pounds per square inch	500	725	700
Quality of briquet:			
Fresh	D	D	D
Air-dried	C	C	D

All tests without binder failed to produce briquets that could be taken from the mold without breaking.

With 6 per cent of water gas pitch binder fairly good briquets were made from this lignite either in a dried or undried condition; 8 per cent of the water gas pitch made excellent briquets when the fuel was dried; 4 per cent of the water-gas pitch made a fair briquet of the undried fuel.

As low as 4 per cent of wheat flour made excellent briquets of the undried fuel, but even 8 per cent was not sufficient to briquet the dried fuel containing 5 per cent of moisture. The reason may be found in the fact that to obtain the adhesive power of the flour it must absorb a large quantity of water and if the coal is too dry it absorbs the water from the steam used for heating, and the flour is not thoroughly glutinized.

The undried fuel and 6 per cent of cell pitch made satisfactory briquets although they required careful handling when fresh from the press. Those made with 8 per cent were much stronger when fresh, but when cold differed very little from the 6 per cent briquets. Comparison of tests Nos. 109 and 147 shows that briquets in which 15 per cent of moisture was present were much stronger than those with 5 per cent of moisture.

Sulphite liquor did not make a satisfactory binder either with the dried or undried fuel.

Five per cent of cornstarch with the undried fuel was not sufficient to produce a briquet that was strong when fresh. With the fuel dried to contain only 5 per cent of moisture, 7 per cent of cornstarch did not give satisfactory briquets, again illustrating the important part that the proper proportion of moisture plays in briquetting lignite.

The source and analysis of this fuel sample are to be found under "Details of Briquetting Tests."

TESTS WITH PITTSBURGH BITUMINOUS SLACK.

The data obtained from laboratory tests of Pittsburgh bituminous slack and various binders are given in the following tables:

Laboratory briquetting tests of Pittsburgh slack with water-gas pitch binder.

	Test No.		
	L 61.	L 68.	L 69.
Briquetting temperature, °F	158	151	194
Binder:			
Lot No	26	26	26
Amount used, per cent	6	6	8
Method of heating used	S. J.	S. J.	S. J.
Weight of:			
Mixture used, grams	200	200	200
Briquet, average, grams	....	198	196
Condition of fuel, dried or undried	Undried.	Undried.	Undried.
Pressure used, pounds per square inch	4,000	4,000	4,000
Crushing strength, pounds per square inch	2,220	2,100	2,800
Quality of briquet:			
Fresh	A	A	A
Air-dried	A	A	A

Laboratory briquetting tests of Pittsburgh slack with cornstarch binder.

	Test No. L 70.
Briquetting temperature, °F	203
Binder:	
Lot No	35
Amount used, per cent	30
Method of heating used	S. J.
Weight of:	
Mixture used, grams	200
Briquet, average, grams	213
Condition of fuel, dried or undried	Undried.
Pressure used, pounds per square inch	4,000
Moisture added in heating, per cent	6.5
Crushing strength, pounds per square inch	2,100
Quality of briquet:	
Fresh	A
Air-dried	A

Laboratory briquetting tests of Pittsburgh slack with hardwood-tar pitch binder.

	Test No.				
	L 60.	L 59.	L 65.	L 62.	L 66.
Briquetting temperature, °F	158	158	167	158	167
Binder:					
Lot No	29	29	29	29	29
Amount used, per cent	[a] 4	[a] 6	[b] 4	[b] 6	[b] 8
Method of heating used	S. J.	S. J.	S. J.	S. J.	S. J.
Weight of:					
Mixture used, grams	200	200	200	200	200
Briquet, average, grams	200	200	200	200	200
Condition of fuel, dried or undried	Undried.	Undried.	Undried.	Undried.	Undried.
Pressure used, pounds per square inch	4,000	4,000	4,000	4,000	4,000
Crushing strength, pounds per square inch	1,750	1,600	1,950	2,275	2,100
Quality of briquet:					
Fresh	A	A	A	A	A
Air-dried	A	A	A	A	A

[a] Binder mixed cold. [b] Binder used in melted form.

Laboratory briquetting tests of Pittsburgh slack with cell-pitch binder.

	Test No.			
	L 92.	L 88.	L 87A.	L 87B.
Briquetting temperature, °F	151	156	194	194
Binder:				
Lot No	27	27	27	27
Amount used, per cent	2	4	5	5
Method of heating used	S. J.	S. J.	S. J.	S. J.
Weight of:				
Mixture used, grams	200	200	200	200
Briquet, average, grams	205	206	....	204
Condition of fuel, dried or undried	Undried.	Undried.	Undried.	Undried.
Pressure used, pounds per square inch	6,000	6,000	6,000	6,000
Moisture added in heating, per cent	4.5	4.5	....	....
Length of heating, minutes	½	½	½	½
Condition of mold	Hot.	Hot.	Hot.	Hot.
Reduction of volume by pressing, per cent	37	41	39	39
Crushing strength, pounds per square inch	1,800	2,850	....	3,300
Quality of briquet:				
Fresh	B	B	B	B
Air-dried	A	A	A	A

Laboratory briquetting tests of Pittsburgh slack with cell-pitch binder—Continued.

	Test No.			
	L 89.	L 90.	L 91.	L 93.
Briquetting temperature, °F	158	144	158	143
Binder:				
Lot No	27	27	27	27
Amount used, per cent	6	8	8	10
Method of heating used	S. J.	S. J.	S. J.	S. J.
Weight of:				
Mixture used, grams	200	200	205	200
Briquet, average, grams	206	204	204	205
Condition of fuel, dried or undried	Undried.	Undried.	Undried.	Undried.
Pressure used, pounds per square inch	6,000	6,000	6,000	6,000
Moisture added in heating, per cent	4.5	3.0	2.5	4.0
Length of heating, minutes	½	⅓	⅓	½
Condition of mold	Hot and cold.	Hot and cold.	Cold.	Cold.
Reduction of volume by pressing, per cent	37	36	36	39
Crushing strength, pounds per square inch	3,800		3,800	3,700
Quality of briquet:		3.400		
Fresh	A	[a] A	A	[a] A
Air-dried	A	A	A	A

[a] Material stuck to plunger, showing excess of binder.

Laboratory briquetting tests of Pittsburgh slack with sulphite-liquor binder.

	Test No.					
	L 72.	L 73.	L 74A.	L 74B.	L 75A.	L 75B.
Briquetting temperature, °F	66	180	199	199	203	203
Binder:						
Lot No	34	34	34	34	34	34
Amount used, per cent	3	3	3	3	4	4
Method of heating used	Cold.	S. J.	S. J.	S. J.	S. J.	S. J.
Weight of mixture used, grams	200	200	200	200	200	200
Condition of fuel, dried or undried	Undried.	Undried.	Undried.	Undried.	Undried.	Undried.
Pressure used, pounds per square inch	4,000	4,000	4,000	4,000	4,000	4,000
Length of heating, minutes	Cold.	1½	1	½	1	½
Reduction of volume by pressing, per cent	33	29	35	34	33	33
Crushing strength, pounds per square inch	1,700	....	1,400	1,500	1,100	1,800
Quality of briquet:						
Fresh	C	C	B	B	C	B
Air-dried	A	B	A	A	B	A

	Test No.				
	L 76.	L 76B.	L 76C.	L 76D.	L 232.
Briquetting temperature, °F	Cold.	171	203	257	194
Binder:					
Lot No	34	34	34	34	32
Amount used, per cent	10	10	10	10	4
Method of heating used	Cold.	Hot mold only.	S. J.	Gas flame.	S. J.
Weight of:					
Mixture used, grams	200	200	200	200	200
Briquet, average, grams	200	200	....	....	206
Condition of fuel, dried or undried	Undried.	Undried.	Undried.	Undried.	Undried.
Pressure used, pounds per square inch	4,000	4,000	4,000	4,000	4,000
Moisture added in heating, per cent	....	....	....	....	4.0
Length of heating, minutes	Cold.	Hot.	½	....	½
Reduction of volume by pressing, per cent	36	36	36	40	44
Crushing strength, pounds per square inch	3,500	3,900	....	....	1,625
Quality of briquet:					
Fresh	A	A	C	D	A
Air-dried	A	A	B+	C	A

Laboratory briquetting tests of Pittsburg slack with sulphite-liquor binder—Continued.

	Test No.			
	L 233.	L 234.	L 235.	L 236.
Briquetting temperature, °F	194	196	189	192
Binder:				
Lot No.	32	32	32	32
Amount used, per cent	6	8	10	12
Method of heating used	S. J.	S. J.	S. J.	S. J.
Weight of:				
Mixture used, grams	200	200	200	200
Briquet, average, grams	205	206	206	206
Condition of fuel, dried or undried	Undried.	Undried.	Undried.	Undried.
Pressure used, pounds per square inch	4,000	4,000	4,000	4,000
Moisture added in heating, per cent	3.5	3.5	4.0	3.5
Length of heating, minutes	½	½	½	½
Reduction of volume by pressing, per cent	44	44	48	47
Crushing strength, pounds per square inch	1,875	2,300	2,725	3,000
Quality of briquet:				
Fresh	A	A	A	A
Air-dried	A	A	A	A

Laboratory briquetting tests of Pittsburgh slack with water-gas pitch and cell-pitch binders mixed.

	Test No. L 94.
Briquetting temperature, °F	194
Binder:	
Lot No.—	
26	W. G. P.
27	C. P.
Amount used, per cent	3 of each.
Method of heating used	S. J.
Weight of:	
Mixture used, grams	200
Briquet, average, grams	206
Condition of fuel, dried or undried	Undried.
Pressure used, pounds per square inch	6,000
Moisture added in heating, per cent	5.0
Length of heating, minutes	¾
Reduction of volume by pressing, per cent	38
Quality of briquet:	
Fresh	[a] C
Air-dried	B

[a] Mixture was too wet.

Pittsburgh slack was easily briquetted with 6 per cent of water-gas pitch. All briquets made of this fuel and binder were of excellent quality.

A test (L 70) with cornstarch and bituminous slack showed that 3 per cent of this binder is sufficient to make excellent briquets of this fuel.

Hardwood-tar pitch was tested with Pittsburgh slack. This binder is soft enough to be cut with the finger nail at ordinary temperatures. For this reason it was with difficulty incorporated with the fuel when cold. Better mixtures were obtained by melting the binder and mixing it with the fuel. In test L 60 the binder and the fuel were mixed by stirring in a mortar. Tests L 65, L 62, and L 66 were made by mixing the binder in a melted condition. This binder made briquets of satisfactory strength when as low as 4 per cent was used, but for commercial purposes 5 to 6 per cent would be required to give the briquet sufficient strength and hardness to withstand transporting into storage. A jet of steam is a satisfactory means of heating the mixture of fuel and molten pitch. This binding material has a strong characteristic creosote odor, and should have good disinfecting properties. The presence of this odor might prevent the use of this binder for household briquets.

Cell pitch was also tested as a binder for Pittsburgh slack—2, 4, 5, 6, 8, and 10 per cent being used. It is interesting to note that only 2 per cent of this binder produced a briquet having a crushing strength of 1,800 pounds per square inch when cold and air-dried. A 6 per cent water gas pitch briquet has a crushing strength of only about 2,100 pounds per square inch. The higher percentages of this binder made stronger briquets. It should be said, however, that when fresh the briquets made with 2, 4, and 5 per cent of this binder were slightly soft. If the mixture is heated with superheated steam, the moisture being thus kept low, there should be no difficulty in producing satisfactory briquets with a low percentage of this binder. The great drawback with this binder is that it is soluble in water and easily leached by a rainstorm, allowing the fuel particles to fall to pieces.

Experiments were made with Pittsburgh slack and 3 to 12 per cent of sulphite-liquor binder. Although 3 per cent of this binder is sufficient to produce briquets that are strong when cold and air-dried, they are fragile when fresh and would not stand commercial handling from the press to storage. It is necessary to use a larger proportion of this binder to make briquets of sufficient strength when fresh than is necessary for a dried and cool briquet. It is therefore desirable that the sulphite liquor be used in as concentrated a form as possible.

A test (L 94) was made with Pittsburgh slack and 3 per cent each of water-gas pitch and cell pitch to determine the waterproofing qualities of the former in connection with the strong qualities of the latter binding material. When fresh, the resultant briquets were very weak and required careful handling, but after having been dried and cooled they were much stronger and appeared to possess satisfactory water-resisting qualities.

TESTS WITH TEXAS LIGNITE.

The data obtained from laboratory tests of Texas lignite (Pittsburgh No. 9 [a]) and various binders are given in the following tables:

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[a] See table, p. 40.

Laboratory briquetting tests of Texas lignite with water-gas pitch binder.

	Test No.				
	L 187.	L 188.	L 189.	L 190.	L 191.
Size as used:					
Over $\frac{1}{4}$ inch, per cent	7.2	7.2	7.2	7.2	7.2
$\frac{1}{10}$ to $\frac{1}{4}$ inch, per cent	30.6	30.6	30.6	30.6	30.6
$\frac{1}{20}$ to $\frac{1}{10}$ inch, per cent	30.2	30.2	30.2	30.2	30.2
$\frac{1}{40}$ to $\frac{1}{20}$ inch, per cent	15.9	15.9	15.9	15.9	15.9
Through $\frac{1}{40}$ inch, per cent	16.1	16.1	16.1	16.1	16.1
Briquetting temperature, °F	196	198	192	196	189
Binder:					
Lot No	26	26	26	26	26
Amount used, per cent	4	5	6	7	8
Method of heating used	S. J.	S. J.	S. J.	S. J.	S. J.
Weight of:					
Mixture used, grams	210	211	210	211	210
Briquet, average, grams	208	208	208	208	208
Condition of fuel, dried or undried	Undried.	Undried.	Undried.	Undried.	Undried.
Pressure used, pounds per square inch	4,000	4,000	4,000	4,000	4,000
Moisture:					
In fuel, per cent	18.2	18.2	18.2	18.2	18.2
Added in heating, per cent	5.0	5.5	5.0	5.5	5.0
In briquet, per cent	23.2	23.7	23.2	23.7	23.2
Length of heating, minutes	$\frac{1}{2}$ and $\frac{3}{4}$	$\frac{1}{2}$ and $\frac{3}{4}$	$\frac{1}{2}$ and $\frac{3}{4}$	$\frac{1}{2}$ and $\frac{3}{4}$	$\frac{1}{2}$ and $\frac{3}{4}$
Reduction of volume by pressing, per cent	42	42	43.5	44.5	42.5
Crushing strength, pounds per square inch	400	650	800	675	950
Quality of briquet:					
Fresh	C	C	B	B	A
Air-dried	C	C	B	B	A

Laboratory briquetting tests of Texas lignite with flour binder.

	Test No.						
	L 192.	L 193.	L 194.	L 195.	L 196.	L 197.	L 198.
Size as used:							
Over $\frac{1}{4}$ inch, per cent	7.2	7.2	7.2	7.2	7.2	7.2	7.2
$\frac{1}{10}$ to $\frac{1}{4}$ inch, per cent	30.6	30.6	30.6	30.6	30.6	30.6	30.6
$\frac{1}{20}$ to $\frac{1}{10}$ inch, per cent	30.2	30.2	30.2	30.2	30.2	30.2	30.2
$\frac{1}{40}$ to $\frac{1}{20}$ inch, per cent	15.9	15.9	15.9	15.9	15.9	15.9	15.9
Through $\frac{1}{40}$ inch, per cent	16.1	16.1	16.1	16.1	16.1	16.1	16.1
Briquetting temperature, °F	198	194	196	196	196	198	198
Binder:							
Lot No	31	31	31	31	31	31	31
Amount used, per cent	2	3	4	5	6	7	8
Method of heating used	S. J.	S. J.	S. J.	S. J.	S. J.	S. J.	S. J.
Weight of:							
Mixture used, grams	212	213	213	212	212	212	212
Briquet, average, grams	209	209	210	209	209	208	209
Condition of fuel, dried or undried	Undried.	Undried.	Undried.	Undried.	Undried.	Undried.	Undried.
Pressure used, pounds per square inch	4,000	4,000	4,000	4,000	4,000	4,000	4,000
Moisture:							
In fuel, per cent	18.2	18.2	18.2	18.2	18.2	18.2	18.2
Added in heating, per cent	6.0	6.5	6.5	6.0	6.0	6.0	6.0
In briquet, per cent	24.2	24.7	24.7	24.2	24.2	24.2	24.2
Length of heating, minutes	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Reduction of volume by pressing, per cent	46	46	46	46	46	46	46
Crushing strength, pounds per square inch	750	900	1,200	1,325	1,375	1,450	1,475
Quality of briquet:							
Fresh	B	B	A	A	A	A	A
Air-dried	B	B	A	A	A	A	A

Laboratory briquetting tests of Texas lignite with cell-pitch binder.

	Test No. L 123.
Briquetting temperature, °F	162
Binder:	
Lot No	27
Amount used, per cent	8
Method of heating used	S. J.
Weight of:	
Mixture used, grams	210
Briquet, average, grams	207
Condition of fuel, dried or undried	Undried.
Pressure used, pounds per square inch	6,000
Moisture:	
In fuel, per cent	18.2
Added in heating, per cent	5.0
In briquet, per cent	23.2
Length of heating, minutes	$\frac{1}{2}$
Crushing strength, pounds per square inch	1,250
Quality of briquet:	
Fresh	A
Air-dried	A

Laboratory briquetting tests of Texas lignite with sulphite-liquor binder.

	Test No.						
	L 211.	L 212.	L 213.	L 214.	L 215.	L 216.	L 217.
Size as used:							
Over $\frac{1}{4}$ inch, per cent	7.2	7.2	7.2	7.2	7.2	7.2	7.2
$\frac{1}{10}$ to $\frac{1}{4}$ inch, per cent	30.6	30.6	30.6	30.6	30.6	30.6	30.6
$\frac{1}{20}$ to $\frac{1}{10}$ inch, per cent	30.2	30.2	30.2	30.2	30.2	30.2	30.2
$\frac{1}{40}$ to $\frac{1}{20}$ inch, per cent	15.9	15.9	15.9	15.9	15.9	15.9	15.9
Through $\frac{1}{40}$ inch, per cent	16.1	16.1	16.1	16.1	16.1	16.1	16.1
Briquetting temperature, °F	192	199	196	194	199	194	181
Binder:							
Lot No	34	34	34	34	34	34	34
Amount used, per cent	3	4	5	6	7	8	9
Method of heating used	S. J.	S. J.	S. J.	S. J.	S. J.	S. J.	S. J.
Weight of:							
Mixture used, grams	208	210	210	210	210	210	209
Briquet, average, grams	206	208	207	207	207	206	206
Condition of fuel, dried or undried	Undried.	Undried.	Undried.	Undried.	Undried.	Undried.	Undried.
Pressure used, pounds per square inch	4,000	4,000	4,000	4,000	4,000	4,000	4,000
Moisture:							
In fuel, per cent	18.2	18.2	18.2	18.2	18.2	18.2	18.2
Added in heating, per cent	4.0	5.0	5.0	5.0	5.0	5.0	4.5
In briquet, per cent	22.2	23.2	23.2	23.2	23.2	23.2	22.7
Length of heating, minutes	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
Reduction of volume by pressing, per cent	46	46	45.5	45.5	47	47	47
Crushing strength, pounds per square inch	300	300	300	525	525	625	725
Quality of briquet:							
Fresh	D	C	C	C	C	C	C
Air-dried	D	C	C	C	C	C	B

This lignite was not successfully briquetted without binder. Tests with this fuel and water-gas pitch showed that not less than 6 per cent of binder would give a fair briquet, and that even 8 per cent did not furnish what might be called an excellent briquet. All tests were made on the undried fuel. Three per cent of flour made a good briquet, and 4 per cent produced an excellent briquet in both strength and appearance, although water would disintegrate it in a few hours. This fuel was made into excellent, although not waterproof, briquets with 8 per cent of cell pitch. Nine per cent of sulphite liquor did not make entirely satisfactory briquets.

The source from which this sample was obtained and its chemical analysis are to be found under "Details of Briquetting Tests."

TESTS WITH UTAH SUBBITUMINOUS COAL.

The data obtained from laboratory tests of a sample of Utah subbituminous coal (Pittsburgh No. 36[a]) and various binders are given in the following tables:

Laboratory briquetting tests of Utah subbituminous coal with water-gas pitch binder.

	Test No.	
	L 137.	L 132.
Briquetting temperature, °F	167	162
Binder:		
Lot No	26	26
Amount used, per cent	3	7
Method of heating used	S. J.	S. J.
Weight of:		
Mixture used, grams	200	200
Briquet, average, grams	207	206
Condition of fuel, dried or undried	Undried.	Undried.
Pressure used, pounds per square inch	6,000	6,000
Moisture:		
In fuel, per cent	10.8	10.8
Added in heating, per cent	4.5	4.0
In briquet, per cent	15.3	14.8
Length of heating, minutes	½	½
Reduction of volume by pressing, per cent	40	42
Crushing strength, pounds per square inch	200	1,050
Quality of briquet:		
Fresh	D	B
Air-dried	D	A

Laboratory briquetting tests of Utah subbituminous coal with cell-pitch binder.

	Test No.	
	L 134.	L 133.
Briquetting temperature, °F	164	159
Binder:		
Lot No	27	27
Amount used, per cent	4	7
Method of heating used	S. J.	S. J.
Weight of:		
Mixture used, grams	200	200
Briquet, average, grams	207	208
Condition of fuel, dried or undried	Undried.	Undried.
Pressure used, pounds per square inch	6,000	6,000
Moisture:		
In fuel, per cent	10.8	10.8
Added in heating, per cent	4.5	4.5
In briquet, per cent	15.3	15.3
Length of heating, minutes	½	½
Reduction of volume by pressing, per cent	40	42
Crushing strength, pounds per square inch	1,150	1,600
Quality of briquet:		
Fresh	C	B
Air-dried	A	A

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[a] See table, p. 40.

Laboratory briquetting tests of Utah subbituminous coal with a mixture of water-gas pitch and cell-pitch binders and of water-gas pitch and flour binders.

	Test No.	
	L 136.	L 135.
Briquetting temperature, °F	180	159
Binder:		
Lot No	26 W. G. P. 27 C. P.	26 W. G. P. 31 flour.
Amount used, per cent	3 W. G. P. 4 C. P.	3 W. G. P. 3 flour.
Method of heating used	S. J.	S. J.
Weight of:		
Mixture used, grams	200	200
Briquet, average, grams	207	206
Condition of fuel, dried or undried	Undried.	Undried.
Pressure used, pounds per square inch	6,000	6,000
Moisture:		
In fuel, per cent	10.8	10.8
Added in heating, per cent	4.5	4.0
In briquet, per cent	15.3	14.8
Length of heating, minutes	½	½
Reduction of volume by pressing, per cent	40	40
Crushing strength, pounds per square inch	1,050	1,450
Quality of briquet:		
Fresh	B	B
Air-dried	A	A

This fuel required 7 per cent of water-gas pitch to produce satisfactory briquets. Four per cent of cell pitch was sufficient to make strong briquets when they were cold and air-dried, but when fresh from the press they were rather weak. Probably 5 to 6 per cent of cell pitch would be required to make a commercial briquet.

Two tests, L 135 and L 136, were made to determine whether an addition of water-gas pitch would make cell-pitch or flour briquets sufficiently waterproof for practical use and storage out of doors. After immersion in water for 10 minutes (test L 136) the cell pitch began to leach out, whereas no change was noticed in the flour and water gas pitch briquet (test L 135). After a three-day immersion both briquets were strong enough to be handled when wet. The flour-and-pitch briquet was in better condition than the cell-pitch and water gas pitch briquet. The water in which the briquets were immersed was colored brown by the dissolved cell pitch. There was no evidence of the flour having been leached out.

TESTS WITH WASHINGTON SUBBITUMINOUS COAL.

The data obtained from laboratory tests of Washington subbituminous coal (Pittsburgh No. 35 [a]) and various binders are given in the following tables:

Laboratory briquetting tests of Washington subbituminous coal with water-gas pitch binder.

	Test. No.	
	L 124.	L 125.
Briquetting temperature, °F	155	152
Binder:		
Lot No	26	26
Amount used, per cent	6	8
Method of heating used	S. J.	S. J.
Weight of:		
Mixture used, grams	200	200
Briquet, average, grams	205	205
Condition of fuel, dried or undried	Undried.	Undried.
Pressure used, pounds per square inch	6,000	6,000
Moisture:		
In fuel, per cent	13.8	13.8
Added in heating, per cent	4.5	3.5
In briquet, per cent	18.3	17.3
Length of heating, minutes	½	½
Reduction of volume by pressing, per cent	42	42
Crushing strength, pounds per square inch	1,200	1,825
Quality of briquet:		
Fresh	A	A
Air-dried	A	A

Laboratory briquetting tests of Washington subbituminous coal with wheat-flour binder.

	Test No.	
	L 128.	L 129.
Briquetting temperature, °F	173	180
Binder:		
Lot No	31	31
Amount used, per cent	5	7
Method of heating used	S. J.	S. J.
Weight of:		
Mixture used, grams	200	200
Briquet, average, grams	210	209
Condition of fuel, dried or undried	Undried.	Undried.
Pressure used, pounds per square inch	6,000	6,000
Moisture:		
In fuel, per cent	18.3	18.3
Added in heating, per cent	6.0	6.0
In briquet, per cent	24.3	24.3
Length of heating, minutes	1	1
Reduction of volume by pressing, per cent	41	40
Crushing strength, pounds per square inch	1,500	1,750
Quality of briquet:		
Fresh	A	A
Air-dried	A	A

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[a] See table, p. 41.

Laboratory briquetting tests of Washington subbituminous coal with cornstarch binder.

	Test No.	
	L 130.	L 131.
Briquetting temperature, °F	184	183
Binder:		
Lot No	35	35
Amount used, per cent	5	7
Method of heating used	S. J.	S. J.
Weight of:		
Mixture used, grams	200	200
Briquet, average, grams	208	208
Condition of fuel, dried or undried	Undried.	Undried.
Pressure used, pounds per square inch	6,000	6,000
Moisture:		
In fuel, per cent	18.3	18.3
Added in heating, per cent	6.0	6.0
In briquet, per cent	24.3	24.3
Length of heating, minutes	1	1
Reduction of volume by pressing, per cent	42	42
Crushing strength, pounds per square inch	1,850	2,100
Quality of briquet:		
Fresh	A	A
Air-dried	A	A

Laboratory briquetting tests of Washington subbituminous coal with cell-pitch binder.

	Test No.	
	L 126.	L 127.
Briquetting temperature, °F	161	161
Binder:		
Lot No	27	27
Amount used, per cent	6	8
Method of heating used	S. J.	S. J.
Weight of:		
Mixture used, grams	200	200
Briquet, average, grams	206	205
Condition of fuel, dried or undried	Undried.	Undried.
Pressure used, pounds per square inch	6,000	6,000
Moisture:		
In fuel, per cent	18.3	18.3
Added in heating, per cent	4.0	4.0
In briquet, per cent	22.3	22.3
Length of heating, minutes	½	½
Reduction of volume by pressing, per cent	42	42
Crushing strength, pounds per square inch	1,000	1,400
Quality of briquet:		
Fresh	B	A
Air-dried	A	A

The fuel made excellent briquets with each of the following binders: Six per cent of water-gas pitch; 5 per cent of wheat flour; 5 per cent of cornstarch; and 6 per cent of cell pitch. More than the above proportions of binder should not be required to make satisfactory briquets. In the case of flour and cornstarch the compressive strength of the 5 per cent briquets indicates that probably 3 per cent of either of these binders would be sufficient to produce a briquet of satisfactory strength for all purposes. The flour, cornstarch, and cell pitch would crumble in water and therefore would have to be stored under cover.

SUMMARY OF LABORATORY TESTS OF BINDERS.

In the following table are recorded the results of the laboratory tests of various binders and fuels as detailed above:

Summary of results of laboratory briquetting tests of various fuels and binders.

Fuel.	Binder.	Smallest per cent that made satisfactory briquet.	Crushing strength of briquet made with minimum of binder.	Crushing strength of briquet made with 6 per cent of binder.	Weather-resisting qualities of 6 per cent briquet.
Pittsburgh slack	Water-gas pitch	[a] 6.0	2,220	2,220	Excellent.
	Cornstarch	3.0	2,100	N. D.	Fair.
	Hardwood-tarpitch	4.0	1,950	2,275	Good.
	Cell pitch	2.0	1,800	3,800	Poor.
	Sulphite liquor	3.0	1,400	1,875	Very poor.
Texas lignite (P-9)	Water-gas pitch	6.0	800	800	Good.
	Wheat flour	3.0	900	1,375	Fair.
	Cell pitch	[a] 8.0	1,250	....	Poor.
	Sulphite liquor	[b] 9.0	725	525	Very poor.
Pennsylvania anthracite culm	Cell pitch	3.0	2,700	....	Poor.
	Sulphite liquor	5.0	2,500	....	Very poor.
North Dakota lignite (P-15)	Water-gas pitch	[b] 8.0	650	300	Fair.
	Wheat flour	3.0	750	1,125	Do.
	Cell pitch	8.0	925	550	Poor.
North Dakota lignite (P-17)	Water-gas pitch	[b] 8.0	350	400	Fair.
	Wheat flour	5.0	1,125	1,200	Do.
	Sulphite liquor	[b] 9.0	300	....	Very poor.
Philippine lignite	Water-gas pitch	6.0	1,400	1,400	Good.
	Wheat flour	4.0	1,550	1,550	Fair.
	Cornstarch	[b] 5.0	1,225	....	Do.
	Cell pitch	6.0	925	925	Poor.
	Sulphite liquor	[b] 8.0	725	600	Very poor.
Utah subbituminous (P-36)	Water-gas pitch	7.0	1,050	....	Good.
	Cell pitch	4.0	1,150	....	Poor.
Washington subbituminous (P-35)	Water-gas pitch	6.0	1,200	1,200	Good.
	Wheat flour	[a] 5.0	1,500	....	Fair.
	Cornstarch	[a] 5.0	1,850	....	Do.
	Cell pitch	6.0	1,000	1,000	Poor.

[a] Lowest percentage used in tests, but not necessarily the lowest that would furnish a satisfactory briquet.
[b] This percentage was not sufficient to make entirely satisfactory briquets, but was the highest used in the tests.

CONCLUSIONS FROM LABORATORY TESTS.

Following are presented conclusions derived from the tests:

1. Different binders require different methods of heating to obtain the best results.

2. The various classes of fuels require different methods of treatment to produce the best briquets.

3. Lignites, to produce the strongest briquets, generally require drying before being mixed with binder, but for the best results some moisture must be allowed to remain in the fuel.

4. Six per cent of water-gas pitch made satisfactory briquets from Pittsburgh slack, Texas lignite, Philippine lignite, and Washington subbituminous coal; 7 per cent was sufficient to satisfactorily briquet Utah subbituminous coal.

5. Three per cent wheat flour made satisfactory briquets from samples of Texas and North Dakota lignite;[a] 4 per cent made satis-

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[a] One sample of North Dakota lignite required 5 per cent.

factory briquets from undried Philippine lignite; and 5 per cent was more than sufficient to make satisfactory briquets from Washington subbituminous coal.

6. Cornstarch gave practically the same results as wheat flour, 3 to 5 per cent being required to make a satisfactory briquet from the various fuels.

7. Four per cent of hardwood-tar pitch made strong briquets of Pittsburgh bituminous slack. The strong characteristic odor of this material may be an objection to its use.

8. Two per cent of cell pitch made strong briquets with Pittsburgh bituminous slack. As this material is soluble in water, it would not make briquets suitable for storage in the open but if stored under cover the briquets will stand up indefinitely. The effect of moisture on this binder being detrimental to its binding qualities, it is not surprising that 8 per cent was required to briquet lignite from Texas and North Dakota, whereas 4 per cent was sufficient to briquet a sample of Utah subbituminous coal. Six per cent was required to briquet Philippine lignite and Washington subbituminous coal. The briquet having the greatest compressive strength was made of Pittsburgh slack and 6 per cent of cell pitch. The briquet broke at a pressure of 3,800 pounds per square inch, whereas a 6 per cent water gas pitch briquet of this coal broke at a pressure of 2,220 pounds per square inch.

9. Three per cent of sulphite liquor was sufficient to briquet Pittsburgh slack and 5 per cent was sufficient to briquet anthracite culm. Less satisfactory results were obtained by mixing this material with lignites. It was found that 9 per cent of this binder was not sufficient to briquet Texas, North Dakota, or Philippine lignite. The moisture in these fuels seemingly affects the binding qualities of this material.

SULPHITE PITCH AS A BINDER.

DERIVATION OF THE PITCH.

A new binding material called "sulphite liquor" has been suggested for briquetting, but more recently a product called "sulphite pitch," obtained from this sulphite liquor, has attracted considerable attention and obviously possesses valuable properties as a binder.

In the sulphite process of manufacturing paper pulp the wood under pressure is boiled with sulphurous acid, or with acid sulphite of calcium and magnesium. The action of sulphurous acid under pressure and at a high temperature upon the lignin and other incrusting matters of the wood fiber is probably a hydrolysis; that is, the complex molecules of the lignin, etc., are broken down, and the resulting products, largely organic acids and aldehydes, become soluble in the liquor.

The waste liquors are light brown and contain much matter extracted from the wood. Until recently they had no commercial value and their proper disposal was often a serious matter, as they polluted streams into which they were emptied, killing the fish.

PREPARATION AND USE IN GERMANY.

Several patents have been obtained for converting the waste liquors into fertilizers, adhesive material, or other commercial products; but the most promising way of utilizing them at present seems to be by making a concentrated product known as "sulphite liquor," or a solid form known as "sulphite pitch" or "cell pitch" (selpech).

The method of preparing sulphite liquor or cell pitch from these wastes, according to W. Sembritzki,[a] manager of the Walsum paper mills (Germany), is as follows:

> At the Walsum factory the liquors have a specific gravity of 1.05 and an acidity, calculated as sulphur dioxide, of 0.32 per cent. The thick sirup, density 35° B., from the evaporators has the following composition: Water, 28.88 per cent; insoluble matter, 13.96 per cent; extract, 57.16 per cent; tanning matters, 22.96 per cent; nontannins, 34.24 per cent. The solid cell pitch contains: Water, 13.76 per cent; soluble extract, 86.60 per cent; tanning matters, 31.84 per cent; nontannins, 54.76 per cent. The nontannins of this sirup consist of organic matter, 24.76 per cent; mineral matter, 9.44 per cent. The nontannins of the cell pitch consist of organic matter, 36.08 per cent; mineral matter, 18.68 per cent.
>
> If the evaporators are made of iron, it is necessary to neutralize the liquor with lime before concentration, and the incrustation of the tubes with calcium compounds is somewhat troublesome. If copper evaporators are used, the liquors may be concentrated in their acid state. If the concentrated liquor is to be used for briquetting flue dust, neutralization with lime is essential to the proper working of the briquets in the blast furnace. If, on the other hand, the concentrated liquors are intended for tanning purposes, neutralization is a drawback, as the calcium compounds make the leather brittle.
>
> The success of the Walsum experiments is attributed in large part to the sextuple-effect Kestner evaporator used. Each effect has a heating surface of 55 square meters; the first vessel is heated with steam at 3 to 4 atmospheres and the boiling point in the last effect is 50° C. The liquor requires about three hours to reach a concentration of 35° B. The sirup is converted into solid pitch by two steam-heated drums which dip below its surface. The first drum concentrates the sirup from 35° B. to 60° B.; the second converts it into a solid film, which is removed with a scraper. Ten kilograms of waste liquor yield 1 kilogram of dry pitch. The fuel consumption is 1 ton of coal per ton of pitch. It is stated that a selling price of $9.50 a ton would show a good profit.
>
> The pitch has the appearance of black opaque resin, but is quite soluble in water. It is used as a binder for fuel and ore briquets. By its use the dust from blast furnaces, containing 40 per cent of iron and hitherto a waste product, has been formed into briquets for resmelting. It has also been used as a dressing for coarse canvas, etc. Large quantities of the sulphite liquor, having a density of about 35° B., are shipped from Germany to England in iron drums. The liquor is used in England as a binder for the sand cores and molds used in casting, and is sold there at $12.50 a ton.

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[a] Sembritzki, W., Preparation of cellulose pitch from waste sulphite liquor: Wochbl. Papier-fabr., 1908 (39), p. 658.

In a report made in 1909 George E. Eager,[a] United States consul at Barmen, Germany, states that sulphite pitch is intensely glutinous and its binding power high. According to Mr. Eager, 7 to 10 per cent of coal tar is needed in briquetting bituminous coal, but the same results can be obtained by the use of 5 per cent of sulphite pitch, and some kinds of coal or ore can be briquetted by using only 2 to 3 per cent. Sulphite pitch burns without smoke or odor and is an ideal fuel for the household, as well as for industrial purposes. The use of briquets made with this sulphite pitch will help to solve the smoke problem in cities. Coke briquets made with this new binder have been tried in blast furnaces and on torpedo boats with promising results. Sulphite pitch does not soften under heat and burns at a high temperature. It can be ground to any consistency; it can be obtained at a low price where there are cellulose mills. Anthracite briquets for household use manufactured with sulphite pitch burn without smoke or odor.

Regarding other uses of sulphite pitch and its composition, the report states:

> Recent attempts to briquet coke gravel and dross show that the resultant briquet can be considered a perfect substitute for coke. Practical trials of the briquets in both blast and cupola furnaces have shown that the briquets do not fall to pieces under the highest temperature, but burn while gradually shrinking. Fine ore, bog-iron ore, brown ore, manganese ore, oxide, furnace cadmia (iron dust from blast furnaces), and other ores can all be briquetted by the use of sulphite pitch and successfully melted in the furnace. All attempts to briquet the above materials with coal-tar pitch have failed, because the binding agent burned at a lower temperature, leaving the material in dust, as before. With sulphite pitch it is possible to briquet furnace cadmia so that it can be melted in a blast furnace, making possible a great saving to the iron industry.

In general, sulphite pitch consists of the following substances: Fixed carbon, 25 to 35 per cent; volatile matter, 50 to 60 per cent; ash, 8 to 12 per cent; and water, 10 to 15 per cent. The percentage of ash can be materially reduced. Through the origin of sulphite pitch its ashes contain sulphur up to 20 per cent, or 2.5 per cent of the sulphite pitch. The sulphur is combined with iron and lime, so that the sulphur remains in the ashes and can not do any damage. Sulphite pitch is soluble in water, and briquets made from it are not waterproof. The sulphite-pitch briquet is, however, more waterproof than the lignite briquet, the making of which has become a flourishing industry. The sulphite briquet is not hygroscopic and can be made absolutely waterproof by a special treatment.

The production of sulphite pitch, as well as its use in the process of briquetting, call for special processes and machinery which have taken years of expensive experiment to develop successfully, and both the material and its use for briquetting are patented in all the principal countries.

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[a] Daily Consular and Trade Reports, No. 3361.

Sulphite pitch will not in any way interfere with coal-tar pitch in its use for briquetting bituminous coals, but the superiority of sulphite as a binding agent makes possible its use in the briquetting of harder coals and cokes, also iron dust and ores.

THE POLLACSEK BRIQUETTING PROCESS.[a]

The Pollacsek briquetting process, which employs the waste liquor of the sulphite paper-making process as a binder, has been adopted by the Hungarian Government for its collieries, and that Government has erected the machinery for the first plant. It is estimated that a plant in the United States producing 10 tons daily would cost about $5,000 and that the cost of operation would not exceed 60 cents a ton and might be as low as 40 cents in favored places.

Fine coal or slack is used, pieces above a quarter of an inch being crushed. Such crushing is necessary, because any larger pieces of coal would be shattered in the molds of the press, and as there would be no binder between the shattered fragments, the briquets would not be strong enough to stand transportation.

The inventor has a process by which the waste liquor of the pulp mills may be evaporated to a sirup or reduced to a dry powder for convenience in transportation. In the United States the removal of free acid is accomplished by the use of lime. The evaporated sulphite liquor has a sirupy consistency and considering its price and efficacy is the best core binder for foundry use known to-day. It is probable that about the same method of removing free acid is used in the Pollacsek process.

In view of the fact that in making fuel briquets only 3 to 5 per cent of this binder is used, its cost per ton of coal briquetted is small. Another point in favor of the process is that by utilizing the waste liquor from the pulp mills it protects streams from pollution by the liquor.

If the binder is in the form of a sirup, it is diluted; if in the form of solid pitch, it is dissolved in the proper quantity of water. From the mixer the briquet material passes into a rotary kiln, where it is heated and partly dried. The success of the process depends on maintaining the right temperature, for the product goes directly from the kiln to the briquetting press. If the temperature varies only 10° F. either way from the standard, the briquets are not hard or strong enough to stand transportation from the press.

If the kiln dries the material enough and the temperature in the kiln is kept at the right point, the coal will stick together when pressed, but will not adhere to the molds.

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[a] Information furnished by Richard Moldenke, consulting engineer.

If the briquets are not to be waterproofed, they go through a drying oven directly to the cars for shipment. If they are to be waterproofed, they pass from the drying oven through an emulsion of bitumen and water and again through a drying oven, whence they are delivered to the cars. As little labór is needed and the cost of binder is small, claims of great cheapness are made for the process. The secrets of the process are the proper mixing of the coal and binder, the proper control of the kiln temperature, and the weatherproofing of the briquets.

The briquets made by the Pollacsek process are hard, stand rough handling, and are sufficiently weatherproof for every purpose.

The briquetting section of the Bureau of Mines has made laboratory tests with this sulphite pitch, the results of which are published in this bulletin on previous pages.

APPARATUS FOR BRIQUETTING COAL AND COKE WITH CELL PITCH.

The briquetting of coal and coke (with cell pitch binder) was first carried on by "Hengstenberg & Benzenberg, Brikettwerk m. b. H." at Ruhrort, and later at Ruhrrevier and Stettin, Germany.

For the production of cell-pitch briquets essentially the same apparatus is used as for briquetting with coal-tar pitch. Of especial importance is the best possible mixing and kneading of the binding material to be briquetted with superheated steam. Large-sized briquets are pressed with a high pressure, and for this purpose presses are built sufficiently strong to exert a pressure of 7,000 to 8,500 pounds per square inch. For the smaller briquets a lower pressure can be used. Egg-shaped briquets can be produced with cell pitch on the same presses on which coal-tar pitch briquets are made.

WEATHERPROOFING TREATMENT.

Weatherproofing is accomplished by heating the briquet or by a previous treatment of the briquetting material.

The after-heating is the older method and consists of partly coking the sulphite pitch. This produces a briquet that is waterproof and weatherproof, as well as unusually hard and firm and rough on the surface. The method is in many cases economical and worth practicing if a cheap source of heat is available. The briquets, dried by blast-furnace gases at a temperature of 300° C., furnish weather-resisting coke briquets.

The latest method of waterproofing sulphite-pitch briquets consists of the addition of certain chemicals (at the present time a secret) directly to the briquet material before pressing. The additional cost is about 35.7 cents per ton of finished briquets. This increased cost should be less if the chemicals can be bought more cheaply in consequence of an enlarged use for briquetting.

APPLICATION AND COST OF PRODUCTION.

The cost in Germany of building a two-press plant having an hourly capacity of 5 tons and producing yearly 60,000 tons is as follows:

Cost of two-press cell-pitch briquetting plant in Germany.

Item.	Marks.	Dollars.
Ground	30,000	7,140
Building, including foundation and building stone	50,000	11,900
Machinery, power, lighting, etc	175,000	41,650
Tools, etc	10,000	2,380
Spur track	25,000	5,950
Miscellaneous	5,000	1,190
Total	295,000	70,210

The cost per ton of briquets, including cell pitch but not the raw material, on the basis of a production of 60,000 tons per year, is as follows:

Cost per ton of briquets, including sulphite pitch.

Percentage of sulphite pitch added.	Cost per ton.	Percentage of sulphite pitch added.	Cost per ton.
4	$0.72	6½	$0.96
4½	.77	7	1.008
5	.82	7½	1.056
5½	.864	8	1.104
6	.912		

The cost of the after treatment of the briquets to make them waterproof must be determined separately for each case. It is estimated, however, at present as not more than 36 cents per ton.

To this cost of briquetting and cost of after treatment are also to be added the cost of the raw material, as well as the royalty. Using as a basis plants already operating in Germany, a royalty of 1 mark or 24 cents per ton of briquets is assumed.

CELL PITCH FOR BRIQUETTING FINE ORES, FLUE DUST, AND THE LIKE.

Cell pitch possesses manifest advantages over coal-tar pitch for briquetting fine ore, flue dust, etc. Its solubility in water does not cause disintegration of the briquets by the steam present in the flue of the blast furnace. The sulphite-pitch ore or flue-dust briquets do not fall to pieces, and the small sulphur content of the binding material exerts no bad effect.

CELL-PITCH EXPERIMENTS OF DR. TRAINER.

The results of cell-pitch experiments by Dr. Trainer (Gewerkschaft Eduard) are essentially the same as those in the above-described bituminous and coke briquetting by means of cell pitch. The briquetted material, after the addition of the required quantity of sulphite pitch, was treated thoroughly in a mixing or kneading machine with superheated steam and was immediately pressed under the high pressure of 7,000 to 8,500 pounds per square inch. The cost of installing a two-press plant for fine ore or flue dust is about as high as for fuel, namely, about $70,210. The briquetting cost for ore briquets, in consequence of their high specific gravity which allows a larger capacity of the pressby weight, is about $0.13 less per ton of briquets than for coal briquets, as shown in the following table:

Cost per ton of briquets, with various percentages of sulphite pitch.

Percentage of sulphite pitch.	Cost per ton.	Percentage of sulphite pitch.	Cost per ton.
4	$0.59	6½	$0.83
4½	.64	7	.88
5	.69	7½	.93
5½	.73	8	.97
6	.78		

It is only in rare cases that it is necessary to waterproof and weatherproof ore briquets. When this is necessary the cost of the briquetting is increased 24 to 36 cents per ton.

The cell-pitch method has found important application in the iron works of the Gewerkschaft Deutscher Kaiser in Bruckhausen, near Ruhrort. An experimental briquetting plant was erected in 1908 to furnish cell pitch at cost to the "Vereinigten Gewerkschaften Eduard und Pionier," Walsum on the Rhine. The results were so favorable that the Gewerkschaft Deutscher Kaiser entered into an agreement with the above firm to furnish sulphite pitch for the briquetting of 400 tons of flue dust per day. The flue-dust cell-pitch briquets are produced with an addition of 4½ per cent of sulphite pitch. The disintegration of the briquets and the small sulphur content of the binding material have not yet proved to have injurious effects. The briquets are completely reduced, and the ore in the same blast-furnace zone is favorably influenced. If, for example, 15 per cent of briquets is added to the charge, and an equal percentage of ore omitted, there is a decrease in flue dust of 30 per cent, as well as an increased production of iron with a smaller use of coke.

LITERATURE ON SULPHITE LIQUOR AND SULPHITE PITCH.

A brief list of literature relative to sulphite liquor and sulphite pitch is presented below:

Ahrens, F. B., Utilization of waste sulphite-cellulose lyes: Chem. Zeitschr., 1905, pp. 40–41; abstracted in Jour. Soc. Chem. Ind., 1905, p. 343.

Krause, H., Contribution to the chemistry of sulphite wood pulp waste liquors: Chem. Ind., 1906 (29), pp. 217–227; abstracted in Jour. Soc. Chem. Ind., 1906, p. 493.

Robeson, J. S., U. S. Patents 833635, 851378, 851379, 851380, 851381; abstracted in Jour. Soc. Chem. Ind., for 1906 and 1907.

Sembritzki, W., Preparation of cellulose pitch from waste sulphite liquor: Wochbl. Papier-fabr., 1908 (39), p. 658; abstracted in Chem. Abstracts, Amer. Chem. Soc. 1908, p. 1885; Manufacture of pulp pitch from waste sulphite liquors and its use in briquetting: Wochbl. Papier-fabr., 1908 (39), pp. 2866–2867; abstracted in Jour. Soc. Chem. Ind., 1908, p. 915.

Knoesel, T., Manufacture of pulp pitch from waste sulphite liquors and its use in briquetting: Wochbl., Papier-fabr., 1908 (39), pp. 3276–3278, 4049.

Eager, George E., Daily Consular and Trade Reports, No. 3361; also published in Power and the Engineer, March 9, 1909, p. 447.

Thorp, F. H., Outlines of industrial chemistry, 1899, p. 503.

Franke, G., Handbuch der Brikettbereitung, vol. 2, 1909, pp. 72–80.

TESTS TO WHICH BRIQUETS WERE SUBJECTED.

PHYSICAL TESTS.

Samples of the better lots of briquets made were subjected to the drop test, the compression test, and the tumbler test to determine their cohesive strength and to show their ability to endure handling; absorption, specific-gravity, and weathering tests were also made.

DROP TEST.

In the drop test 50 pounds of briquets was placed in a drop-bottom box 24 inches square and 12 inches deep inside, supported 6 feet above a concrete floor. The briquets were dropped on the floor; the pieces were gathered up and those that were held by a 1-inch screen square holes) were returned to the box and dropped again. The floor was swept clean before each drop. This procedure was repeated ive times, after which the weight of pieces that would not pass hrough the screen was determined. The results of the test were ound to agree closely with those of the tumbler test, although no attempt was made to standardize the two tests, one being a shatter est, the other being more on the order of an abrasion test.

TUMBLER TEST.

In the tumbler test a weighed quantity of the briquets (about 50 pounds) was placed in a horizontal sheet-steel cylinder, 2 feet in diameter and 3 feet long, and rotated 2 minutes at a uniform speed of 28 revolutions per minute. The contents of the tumbler were then sized by a 1-inch mesh screen, and the part that passed through was screened through a 10-mesh sieve. The weight of the pieces held by each screen was determined and the "percentage held" computed and reported as in the drop test.

ABSORPTION TEST.

The object of the absorption test was to determine (1) the rate of absorption of water by the briquets each day; (2) the time required for the absorption to become practically complete; and (3) the time at which the absorption actually ceased or the briquet disintegrated. The apparatus consisted of a hydrostatic balance with containing tank and four galvanized-iron pans 24 by 36 by 6 inches.

Four Renfrow briquets, two German briquets, or one English briquet were taken as a sample for each representative lot of briquets tested. These briquets had been stored under cover directly after being made, so they may be safely considered as air-dried samples. Whenever possible, briquets with perfect surfaces were used.

The method used in testing was as follows:

(*a*) The sample was weighed in air on the upper part of the hydrostatic balance. (*b*) The sample was then weighed in water on the lower shelf of the balance, the hour and minute of this immersion being noted. (*c*) The sample was removed from the balance, placed in pans, and covered with one-half inch of water. (*d*) Each succeeding day at the same time as the first immersion the operation noted in *b* was repeated. (*e*) The gain in weight was noted each day by subtracting the observation for the previous day from the weight noted in operation *b*. (*f*) This gain in weight was calculated to a percentage of the original weight of the dry briquet, and so recorded each day.

DETERMINATION OF DENSITY.

The apparent specific gravity, being the weight in air divided by the loss of weight in water, was calculated from readings *a* and *b* of the absorption tests. In the earlier tests fragments from the compression tests were used, each piece weighing about 65 grams. These earlier tests were made with a Nicholson hydrometer.[a]

WEATHERING TEST.

To determine the comparative weather-resisting qualities of the briquets and the samples of fuel from which they were made, small piles of each lot of satisfactory briquets and lumps of the raw fuel were exposed to the action of sun, wind, and rain. Plates XVI to

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[a] See Lord, N. W., Experimental work conducted in the chemical laboratory of the United States fuel-testing plant at St. Louis, Mo., Jan. 1, 1905, to July 31, 1906: Bull. 28, Bureau of Mines, pp. 23–28 (reprint of U. S. Geol. Survey Bull. 323).

XXI, made from photographs taken of Pittsburgh tests at various intervals up to 286 days, show the different stages of weathering. The length of time the briquets were exposed before examination, and the condition of the briquets when examined, are stated in the tabulated results of tests. The key to the conditions designated A, B, C, D, and E is that originally stated in Bulletin 332[a] of the United States Geological Survey, and is as follows:

Condition A: Briquets practically in same condition as when put out. Surfaces show no signs of erosion or pitting. Briquets hard, with sharp edges, and fracture same as that of new briquets.

Condition B: Shape of briquets unchanged. Surfaces of those on top of pile have lost luster, with evidences of pitting; corners and edges worn off by erosion. All briquets firm, with fracture practically the same as that of new briquets.

Condition C: Top briquets appear similar to those in condition B, and show signs of further disintegration, having lost original sharp fracture. Erosion more evident on all briquets on outside of the pile. Inside briquets still firm, retaining original characteristics.

Condition D: Top briquets so badly disintegrated that they crumble to pieces on handling. Briquets in center of pile show signs of disintegration; luster of surfaces gone, edges soft, and break easily in the hand. Fracture not so sharp as when newly made, but briquets firm and handled without breaking.

Condition E: Entire pile disintegrated. In many cases the only briquets retaining their original shape are those protected from the weather. Briquets can not be handled safely, but crush easily in hand.

COMPRESSION TEST.

In order to obtain some standard of comparison between the briquets, the crushing strength of many of them was determined on a 200,000-pound Olsen machine. When only a 1-ton lot was made the best briquets were selected for these tests, as it was reasonable to suppose that in making larger quantities the average briquet would be equal to the better ones made in small lots. Of the 5 to 15 ton lots, the average briquets were taken.

The briquets were tested on the machine lengthwise, so that their position gave a uniform area of 28.7 square inches, the cross-section area of the molds. The thickness of the briquets varied from 5.75 to 6 inches, depending on the pressure. Any differences due to lack of parallelism between the ends were automatically corrected by the swiveling head of the machine. Pieces of millboard were placed between the briquets and the steel. The slowest speed of compression was the most satisfactory.

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[a] Report of the United States fuel-testing plant at St. Louis, Mo., Jan. 1, 1906, to June 30, 1907, J. A. Holmes in charge. 1908. 299 pp.

A comparison of the compression tests of briquets made of anthracite coal and briquets made of anthracite and soft coking coal shows that the crushing strength of the latter is less, although it stands the weather somewhat better than the anthracite briquet with pitch alone.

The coke-breeze briquets were far stronger than any others made, as is indicated by the results of the compression tests.

Although the results of the compression tests are to some extent comparable one with another, they do not give the desired information regarding the actual strength or endurance of the briquets, for in some instances the crushing strength is rather high, whereas the briquets themselves could not have been handled to any great extent without breaking. The most satisfactory test for determining the strength of the briquets is afforded by the drop and tumbler tests. These give results that may be compared, and determine the relative strength of the briquets and the amount of handling they will stand in transportation.

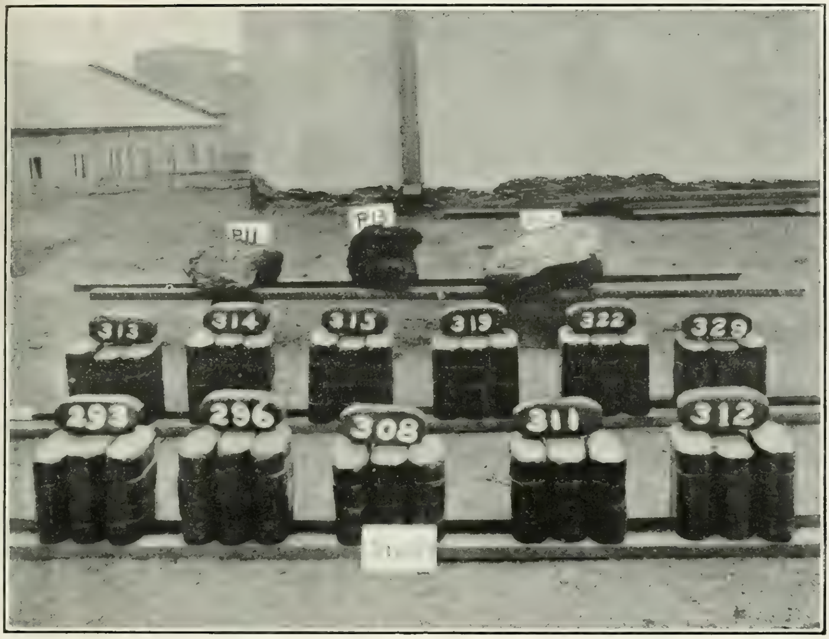
The compression test was discontinued at the St. Louis plant, as the results from briquets made of the same coal and under similar conditions did not check. This difference was probably due to a lack of uniformity in the composition of the various briquets of a test. In the laboratory tests made at Pittsburgh, however, the compression test was found useful to determine the comparative strength of briquets made on the hand experimental press, as in these tests conditions of heating and mixing could be closely controlled, and only five briquets weighing less than one-half pound each were made for each test. This number was too small for the drop or tumbler tests. These briquets, being flat-ended cylinders 3 inches in diameter and about 1¼ inches thick, were suitable for making compression tests on the hydraulic press on which they were formed by removing the mold and substituting flat plates. The results obtained from these tests of laboratory briquets agreed with sufficient closeness to determine the relative strength produced by different percentages of binder.

CHEMICAL TESTS.

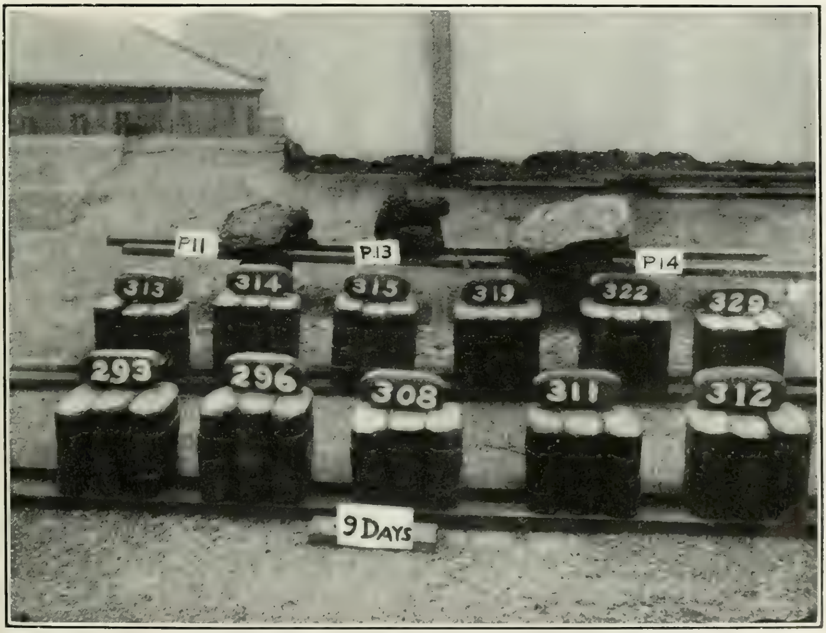
Chemical analyses were made of the fuels and binders used and the briquets manufactured. In most cases proximate analyses only were made of the briquets. Ultimate analyses, as well as proximate analyses, were generally made of the briquetted fuels.

PROXIMATE AND ULTIMATE ANALYSES.

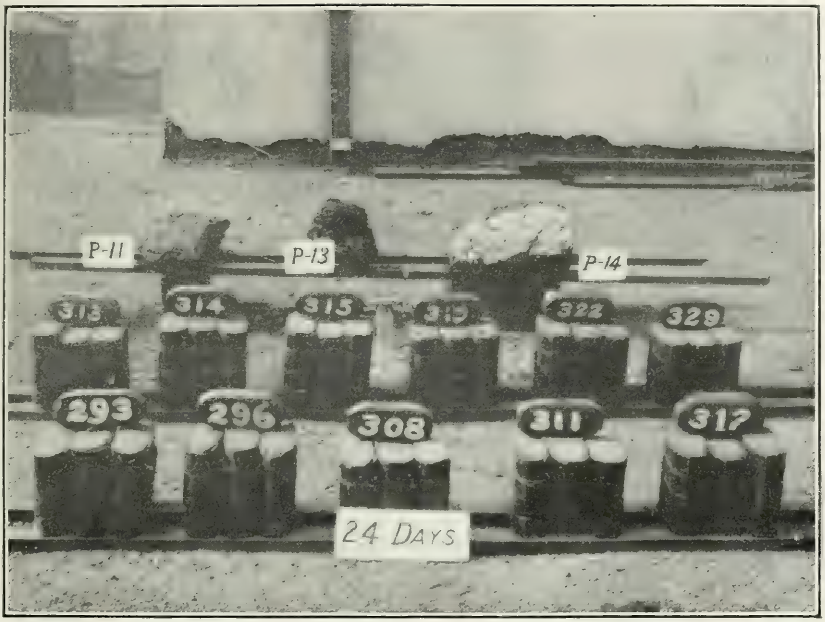
The proximate analyses (including sulphur) herein reported are in terms of "as received." That is, the results of the analyses were calculated on the sample with the moisture in it as received at the



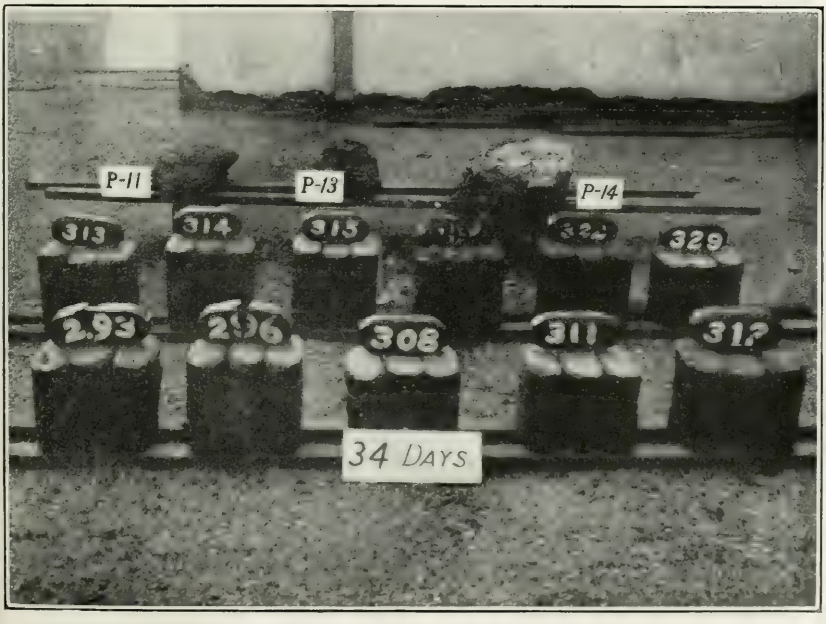
A. BRIQUETS AT BEGINNING OF WEATHERING TEST.



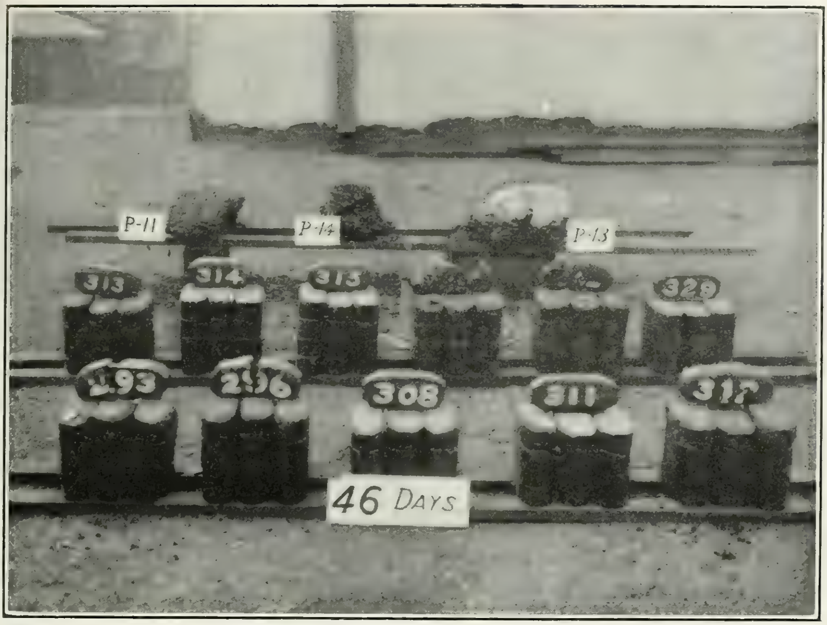
B. BRIQUETS AFTER EXPOSURE FOR 9 DAYS.



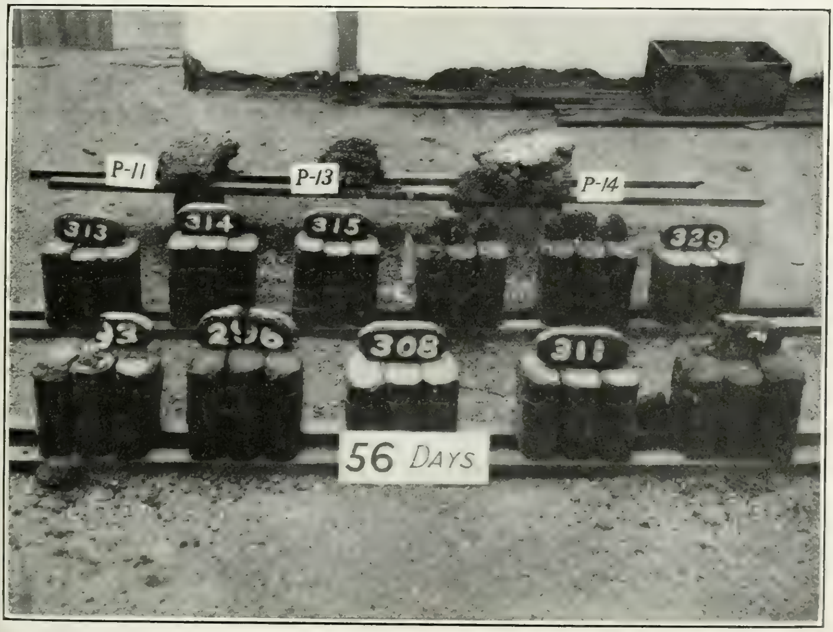
A. BRIQUETS AFTER EXPOSURE FOR 24 DAYS.



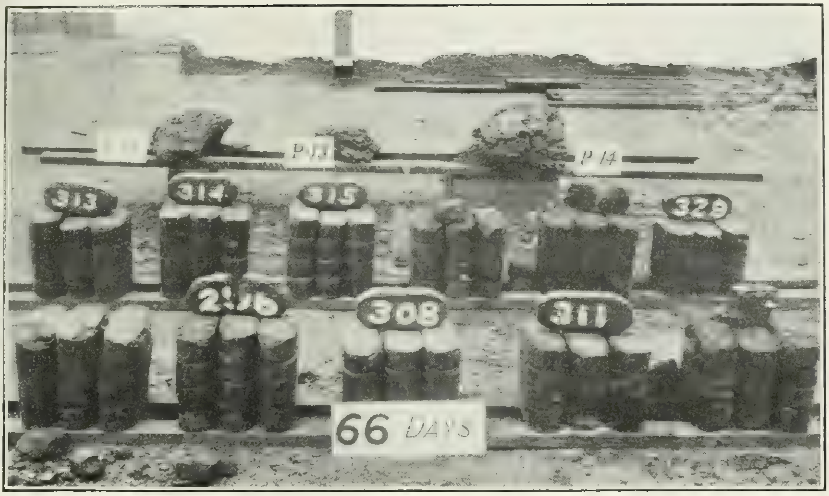
B. BRIQUETS AFTER EXPOSURE FOR 34 DAYS.



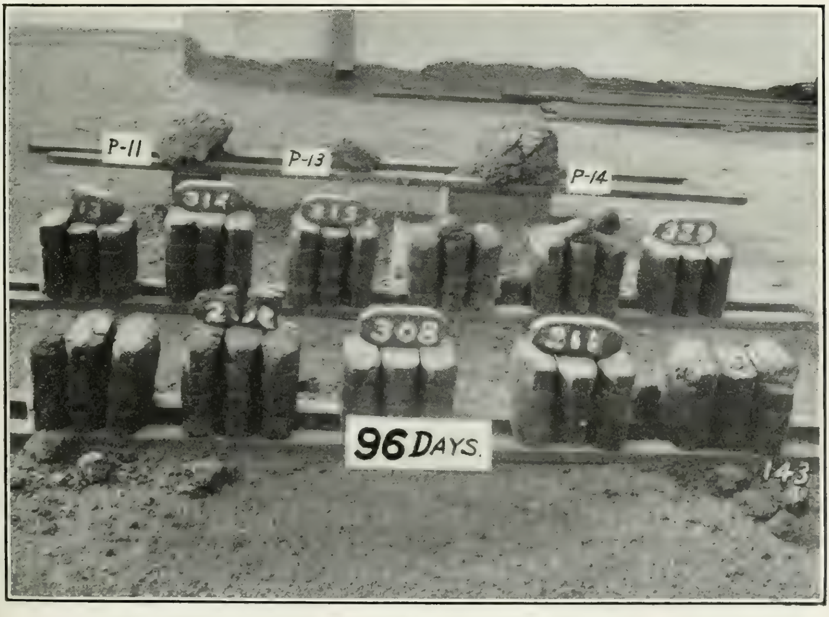
A. BRIQUETS AFTER EXPOSURE FOR 46 DAYS.



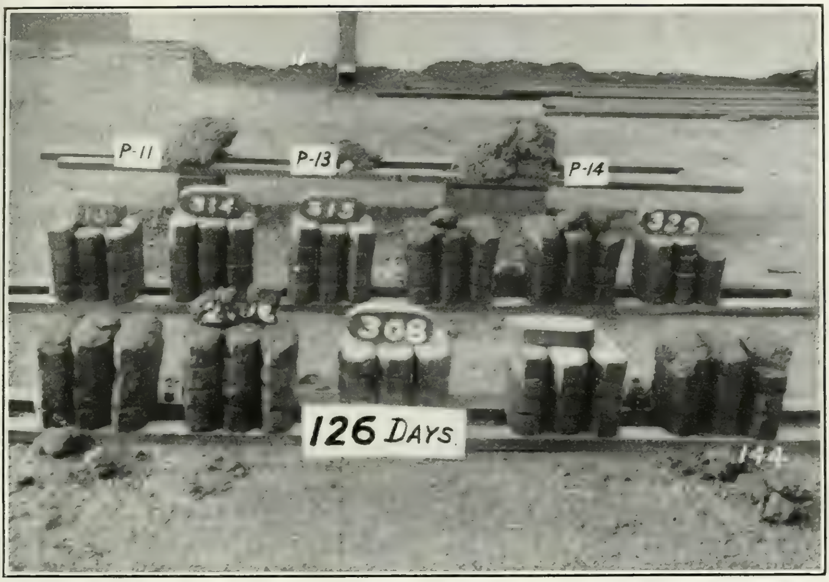
B. BRIQUETS AFTER EXPOSURE FOR 56 DAYS.



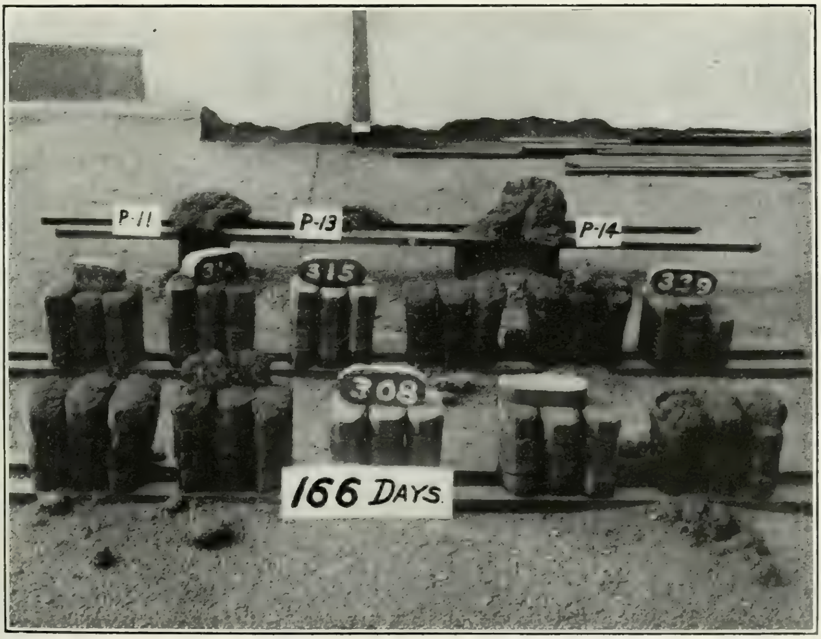
A. BRIQUETS AFTER EXPOSURE FOR 66 DAYS.



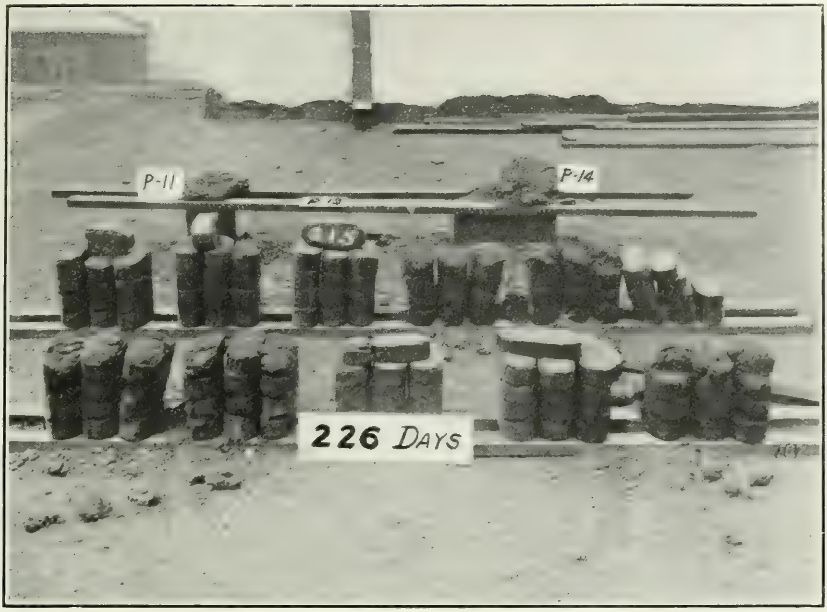
B. BRIQUETS AFTER EXPOSURE FOR 96 DAYS.



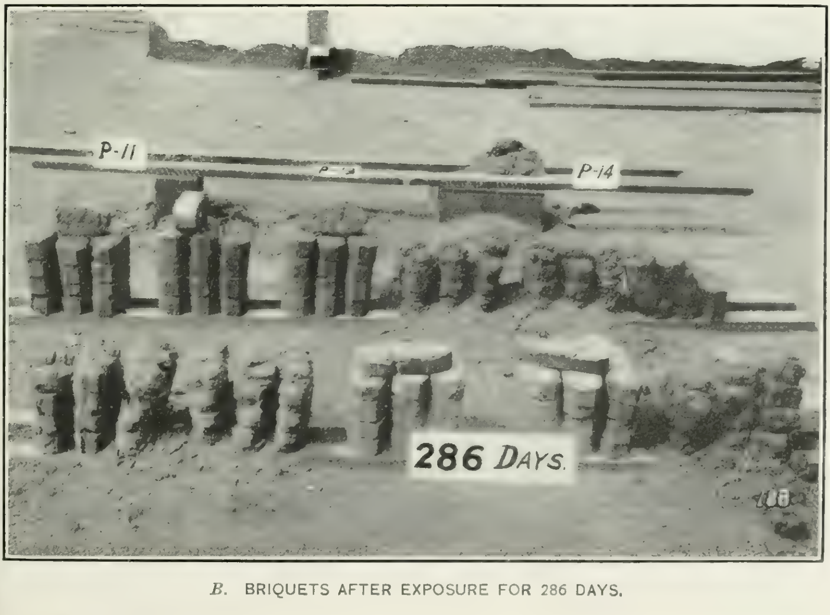
A. BRIQUETS AFTER EXPOSURE FOR 126 DAYS.



B. BRIQUETS AFTER EXPOSURE FOR 166 DAYS.



A. BRIQUETS AFTER EXPOSURE FOR 226 DAYS.



B. BRIQUETS AFTER EXPOSURE FOR 286 DAYS.

laboratory and not on the basis of the dry coal. The ultimate analyses herein reported are on a moisture-free basis, as in this form the analyses are more useful for comparison and future study.

MOISTURE TEST.

In carrying out the lignite tests at Pittsburgh it was necessary to make rapid and frequent moisture determinations for controlling the drying of the fuel. As the usual methods of determining moisture were not rapid enough a special method was devised by F. M. Stanton, chemist in charge of the fuel laboratory. The procedure was as follows: Fifty grams of coarsely crushed lignite was placed in a distilling 200-c. c. flask, covered with 70 c. c. of kerosene, and heated over a gas flame. The moisture driven off was condensed in a Liebig condenser and run into a tall 25-c. c. measuring cylinder or burette. The distillation was carried on until a thermometer in the flask showed a final temperature of 350° F. The quantity of water in the measuring cylinder was noted when the thermometer in the flask registered 250° F., 300° F., and 350° F., and the percentage of moisture in the sample was taken as the percentage of moisture distilled at 300° F. Of course, some of the kerosene distilled over, but it readily separated from the water, and the quantity of the latter in the measuring cylinder could be accurately read.

EXTRACTION TEST.

To determine the percentage of bitumen or natural binding material in the raw or briquetted fuel, samples were extracted with carbon bisulphide in a Soxhlet apparatus in the following manner:

Five grams of the finely ground material was weighed in an extraction thimble and extracted in a flask that had been dried for one-half hour at 108° C., and was cooled in a desiccator and weighed. After the material had been in the extractor five hours the carbon bisulphide in the flask was distilled and recovered in the Soxhlet extractor; the flask and its contents were dried at 108° C. for one hour, cooled, and weighed, and the percentage of material extracted was calculated from the weight of the residue.

From the results of the extraction tests of fuel, bituminous binder, and briquets it was possible to calculate the percentage of pitch binder present in the briquet by the use of the following equation:

$$x=\frac{100\,(A-B)}{C-B}$$

in which x is the percentage of pitch binder present; A is the extraction figure of the briquet, calculated to an "as-received" basis; B is the extraction figure of the coal used, calculated to an "as-received" basis; C is the extraction figure of the pitch binder used, calculated to an "as-received" basis.

COMBUSTION TESTS.

Combustion tests were made of the fuels, binders, and briquets. Heat-value determinations were made by the chemical laboratory using the Mahler bomb calorimeter. The heating value of the materials was also calculated from their analyses, but as the Mahler bomb furnishes more reliable data on the heat value, the results of the bomb tests only are included in this report. The heat values in this report are on a moisture-free basis unless otherwise noted.

STEAMING TESTS.

STATIONARY-BOILER TESTS.

The only method available at St. Louis for determining the relative heating values of briquets consisted in burning them under boilers, the conditions being uniform with those for the steaming tests of coals. These tests were made by the boiler section in every case where there was a sufficient number of briquets, and are reported under "steaming tests" in this bulletin. When coal was not available to make on each machine enough briquets, with the same percentage of binder, for a complete steaming test on both the English and Renfrow briquets, the test was divided into five-hour runs for each machine.

Several small lots of briquets containing various percentages of binder were burned under the boiler to show the behavior of the briquets in the fire and the effect on the quantity of smoke produced, but the main test was of briquets of a uniform percentage of binder. In many tests it was necessary to break up the English briquets in order to obtain capacity on the boiler, although every effort was made to burn them unbroken for comparative results.

Besides these tests of briquets at the plant, two series of tests were run—one using the briquets in locomotive boilers and the other in boilers for house heating. In many tests the product was divided, part being used for a house-heating test and part for a locomotive test.

The combustion tests made with briquetted fuel in stationary, locomotive, and house-heating boilers, and the briquetting test number from which the briquets were obtained, are shown in the table following. This table furnishes a key to the composition, methods of making, and qualities of the briquets used. The steaming tests mentioned in the third column under "Regular steaming test No." are reported in Bureau of Mines Bulletin 23.[a] The locomotive tests are listed in the fourth column. The Seaboard Air Line locomotive tests mentioned are described in Bureau of Mines Bulletin 23,[a] mentioned above, and in Bulletin 34, Bureau of Mines.[b] The locomotive tests of the Pennsylvania 18 (Lloydell) coal are described in Bureau of Mines Bulletin 37.[c] The locomotive tests made by the Atlantic Coast Line Railroad Co. and the Chesapeake & Ohio Railway Co. are also described in Bulletin 37, mentioned above.

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[a] Breckenridge, L. P., Kreisinger, Henry, and Ray, W. T., Steaming tests of coals and related investigations, Sept. 1, 1904, to Dec. 31, 1908. 1912. 380 pp., 2 pls., 94 figs.

The steaming tests of briquets in house-heating boilers are described in Bureau of Mines Bulletin 27.[d] The steaming tests of briquets on the U. S. torpedo boat *Biddle* are described in Bulletin 33 of the bureau.[e]

KEY TO STEAMING TESTS.

A résumé of the locomotive, house-boiler, and torpedo-boat tests is included in this bulletin for the benefit of readers who may not have copies of the bulletins mentioned above.

Key to steaming tests of briquets.

Field designation.	Briquetting test No.	Briquets used in—		
		Regular steaming test No.	Locomotive test No.	House boiler test No.
Alabama 2	131	410		
Alabama 4	123	413		
Argentina 1	180	485		
Arkansas 7	106			
Arkansas 13	[f] 164			45
Do	214			
Do	221			
Illinois 7E	244			48
Illinois 9C	189	492		
Do	190	497		
Do	233			
Do	234			39
Illinois 12BW	166	463	25, 26, 27	
Do	177		28, 29, 32	13
Do	181		30, 31	
Illinois 20, mixed with Kentucky 2B	103			
Do	104			
Illinois 21	113	318		
Illinois 23	116	321		
Do		322		
Illinois 28A	140			
Do	141		1, 4	
Do	142		2	
Do	143		3, 13, 15, 19	
Do	162	459		
Do	163	459		
Illinois 28B	144		16, 17, 18, 20	
Do	158 159 160		21, 22	
Do	161		14	
Illinois 29A	170	465		
Do	171	465		9
Illinois 29B	175	466		12
Illinois 30	225	511		
Do	226	511		
Do	228			

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[a] Pp. 321-329.

[b] Ray, W. T., and Kreisinger, Henry, Tests of run-of-mine and briquetted coal in a locomotive boiler. 33 pp., 9 figs. (reprint of U. S. Geol. Survey Bull. 412).

[c] Goss, W. F. M., Comparative tests of run-of-mine and briquetted coal on locomotives. 58 pp., 4 pls., 35 figs. (reprint of U. S. Geol. Survey Bull. 363).

[d] Randall, D. T., Tests of coal and briquets as fuel for house-heating boilers. 44 pp., 3 pls., 2 figs. (reprint of U. S. Geol. Survey Bull. 366).

[e] Ray, W. T., and Kreisinger, Henry, Comparative tests of run-of-mine and briquetted coal on the torpedo boat *Biddle*. 50 pp., 10 figs. (reprint of U. S. Geol. Survey Bull. 33).

[f] Briquets from this test were used in water-gas machine test.

Key to steaming tests of briquets—Continued.

Field designation.	Briquetting test No.	Briquets used in—		
		Regular steaming test No.	Locomotive test No.	House boiler test No.
Illinois 31	185	491		
Do	186	489		
Do	224			33, 34
Do	237			44
Illinois 33	206			
Do	207			
Do	210			
Do	235			43
Indiana 1B	217		48, 49, 51	37
Indiana 5B	229		47	
Do	230		46	36
Indiana 6B	220		45, 50	
Do	227			38
Indiana 19	165	464	23, 24	
Indiana 20	169		52	
Indian Territory 2B	135			
Do	136			
Do	137			
Do	138	456		
Do	139			
Do	145			
Do	146			
Do	147			
Do	148	453	5, 6, 10, 11, 12	11
Do	149		9	
Do	157	456		10
Do	168			
Indian Territory 2C	153	455		
Do	154	455		
Do	155	455		
Do	156	455		
Indian Territory 9	167	450		
Kansas 2B	182	487	39	40
Do	183	488	38	1
Do	194	495	36	
Do	195			
Do	199		33, 34	
Do	203		37	
Do	204		35	
Kentucky 2B	102		Big Four R. R. preliminary tests.	
Maryland 2	191	493		
Do	192	493		
Do	193	493		
Do	231	518		21, 22, 23
Missouri 10	178	486		2, 3, 4, 5
Do	179	486		
Do	241		59, 61	
Do	245		57, 58, 62, 63, 67, 68	
Do	246		63	
Pennsylvania 15	176	467		
Pennsylvania 15, mixed with Rhode Island 1	184			47
Pennsylvania 16	172	468		
Do	173	468		
Do	174	468		
Pennsylvania 18	196		79, 90	
Do	197	515	72, 73, 74, 75, 76, 87, 89	
Do	200			
Do	201	499		
Do	202	499		
Do	205			
Do	232		78, 80, 81, 82, 86, 88	28, 29
Do	236			30, 31
Do	250			46
Pennsylvania 18 and Rhode Island 1	243			35
Pennsylvania 18 and Miscellaneous 9	238			49
Do	239			50, 51
Do	240			56
Do	248			
Pennsylvania 19	218	508		
Do	219	508		
Do	242			

Key to steaming tests of briquets—Continued.

Field designation.	Briquetting test No.	Briquets used in—		
		Regular steaming test No.	Locomotive test No.	House boiler test No.
Pennsylvania 20	198			26, 27
Do	208	514		
Do	209	514		
Do	212			
Do	213			41, 42
Do	215	512		
Do	216	512		
Pennsylvania 22	211			16, 17
Do	222	510		
Do	223	510		18, 19
Rhode Island 1 and Utah 1	127			
Rhode Island 1 and Utah 2	133			
Rhode Island 1 and Pennsylvania 15	184			47
Rhode Island 1 and Pennsylvania 18	243			35
Tennessee 1	130	409, 411		
Tennessee 4	120	405		
Tennessee 4 and Miscellaneous 5	150			
Do	151			
Tennessee 7A	121	406		
P-11[a]	322			H86, H87
P-14[a]				H88, H89

Field designation.	Briquetting test No.	Briquets used on—		
		Torpedo boat, *Biddle* test No.	Seaboard-locomotive test No.	House boiler test No.
J-6	260	4, 5, 6		
J-9	272	17, 18, 19		
J-11	276	10, 11, 12, 13, 20		
J-13	286		5, 6, 7, 8	
J-13	287		10, 11, 12, 14	(b)
J-15	280, 281		C. & O. locomotive tests; no numbers given.	
J-16			Atlantic Coast Line locomotive tests.	
J-17			Battleship Connecticut.	

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[a] Gas-producer test 188.

[b] Combustion test in kitchen stove made at Pittsburgh; see Bull. 14, Bureau of Mines, 1911, pp. 40-41.

LOCOMOTIVE-BOILER TESTS.

Two hundred tons of Arkansas semianthracite slack coal was made into briquets at St. Louis for the purpose of preliminary tests of their suitability for use in locomotives. Twelve tons of this coal was made on a Renfrow machine into 10-ounce biscuit-shaped briquets. The remainder was made into briquets 4¼ by 6¾ by 2½ inches, averaging about 3½ pounds each. From 6 to 6½ per cent of pitch was used as a binding material in all these briquets.

After a few tests on a switching engine to determine the best method of firing these briquets, two tests were made on the regular passenger locomotive of the Missouri Pacific Railway from St. Louis to Sedalia, Mo., a distance of 188 miles. On a similar run made by this passenger train, with the same engine and fireman, lump coal was used from the

Consolidated Coal Co.'s No. 17 mine, at Collinsville, Ill., this coal being taken as a fair average of that ordinarily used by the Missouri Pacific Railway Co. The water and coal consumed were in each case carefully weighed, but in these preliminary tests no records were made of the steam pressures and temperatures of the feed water.

The engine steamed freely on each of the three tests. No clinkers were formed on the grates or tube sheet with the Illinois bituminous coal. A light clinker was formed over the grates in both runs with the Arkansas coal, which, however, did not interfere with the engine making the required amount of steam. The tube sheet clinkered on the run using Renfrow briquets, and it was necessary to clean off the clinker at Jefferson City, 125 miles from St. Louis. In both tests the briquets produced little smoke and were reported as being a satisfactory fuel for locomotives in the service of this railroad. The mechanical engineer of the company, under whose supervision these tests were made, expressed the opinion that the advantages gained in burning the briquets were more than sufficient to cover the cost of their manufacture.

In cooperation with the Missouri Pacific, the Lake Shore & Michigan Central, the Chicago, Rock Island & Pacific, the Chicago, Burlington & Quincy, and the Chicago & Eastern Illinois Railroads, 100 locomotive tests were made by the United States Geological Survey to determine the value, as a locomotive fuel, of briquets made from a large number of western coals. All tests were made on locomotives in actual service on the road. In some tests there was small opportunity for procuring elaborate data, but in others, where dynamometer cars were employed, it was possible to obtain more detailed results. The purpose that these tests were intended to serve was not so much to determine the evaporative efficiency of briquets as to investigate their behavior in practical use.

Briquets made from Arkansas semianthracite, two qualities of Indian Territory slack, Indian Territory screenings, Missouri slack, Indiana Brazil Block slack, coke breeze, and a mixture of coke breeze and washed Illinois coal were tested. Comparisons were drawn either with the same coal that was used in the briquet or with coal similar to it. In nearly every test the coal when burned in the form of briquets gave a higher evaporative efficiency than when burned in the natural state. For example, Indian Territory screenings give a boiler efficiency of 59 per cent, whereas briquets made from the same coal give an efficiency of 65 to 67 per cent. Decrease in smoke density, the elimination of objectionable clinkers, and a seeming decrease in the quantity of cinders and sparks are named as the chief reasons for this increased efficiency.

Locomotive tests at Altoona, Pa.—A series of steaming tests on a locomotive was made under the direction of A. W. Gibbs, general superintendent of motive power of the Pennsylvania Railroad Co., by E. D. Nelson, engineer of tests at Altoona, Pa., to determine the comparative evaporative efficiency of briquets and of the run-of-mine coal of which they were made. The coal selected for the tests was taken from a mine working the Lower Kittanning coal bed near Lloydell, Cambria County, Pa. This coal is a very friable, bituminous coal, low in volatile matter. After exposure to the weather for 30 days before being briquetted the lot of coal showed little change except a decided increase in moisture, which, however, was eliminated in the briquetting process. The briquets tested on this locomotive were of two sizes, namely, those from the English machine and those from Renfrow No. 1 machine.[a] The proportion of binding material present ranged from 5 to 8 per cent of water-gas pitch.

The locomotive used for all tests was a simple Atlantic (4–4–2) type of passenger locomotive of the Pennsylvania Railroad Co.'s class E–2a. The following conclusions are warranted from these tests according to W. F. M. Goss:

The evaporation per pound of fuel is greater for the briquetted Lloydell coal than for the same coal in its natural state. This advantage is maintained at all rates of evaporation. The capacity of the boiler is considerably increased by the use of briquetted coal. Briquetting appears to have little effect in reducing the quantity of cinders and sparks; the calorific value of cinders, however, is not so high in the briquetted as in the natural fuel. The density of the smoke with the briquetted coal is much less than with the natural coal. The percentage of binder in the briquet has little influence on smoke density. The percentage of binder for the range tested appears to have little or no influence on the evaporative efficiency.

The expense of briquetting under the conditions of the experiments adds about $1 per ton to the price of the fuel, an amount that does not seem to be warranted by the resulting increase in evaporative efficiency. With careful firing, briquets can be used at terminals with a considerable decrease in smoke. The briquets appear to withstand exposure to the weather and suffer little deterioration from handling.

Tests of briquets on locomotive at Norfolk, Va.—In connection with the work at Norfolk, comparative steaming tests were made in stationary, marine, and locomotive boilers with run-of-mine coal and the same coal formed into briquets of two sizes. The tests in a locomotive boiler were undertaken by W. T. Ray and Henry Kreisinger to add cumulative evidence to work done at other places. They were made possible through the courtesy of the Seaboard Air Line Railway Co. in supplying both the locomotive and the coal used. During the trials the locomotive stood on a side track in the shop yards of the railway company at Portsmouth, Va. No running tests were made.

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[a] For shapes and sizes of these briquets see the description of the Renfrow No. 1 machine (p. 26).

The primary object of the tests was to study the relative performances of the two types of briquets, and of the coal, with reference to efficiency, tendency to smoke, and the ease with which steam could be kept up, when each of the three varieties of fuel was burned at several rates of combustion.

All of the coal was in run-of-mine form from the Turkey Gap mine, Pocahontas No. 3 bed at Ennis, McDowell County, W. Va. Part of it went to the briquetting section of the fuel-testing plant at Norfolk, where it was designated Jamestown No. 13 and made into two sizes of briquets on the English and Renfrow No. 2 machines.[a]

Ray and Kreisinger[b] give the following conclusions from this set of tests:

The combustion of suitable fuel can be kept at about the same completeness over a wide range. This is the result of the scrubbing action of rapidly moving currents of gases. In the case of combustion in the fuel bed, the CO_2 formed at the surface of the particles of fuel is replaced by fresh uncombined oxygen.

At low rates of working, run-of-mine coal gives a higher equivalent evaporation than briquets; at medium rates there is little difference; at high rates, briquets do considerably better. There is little difference between the large and the small briquets; the larger ones crumble less. The smaller briquets are easier to fire than are the larger ones; either form gives the fireman far less work and trouble than run-of-mine coal. In sparks briquet fires lose less than coal fires. On roads having heavy grades it will probably pay well to burn briquets, at least part of the time.

The high-capacity test run with briquets (test 14) was by no means the upper limit of fairly efficient combustion and evaporation. These particular briquets produced about as much smoke as the coal under similar conditions; some of the blame for this tendency to smoke may rest on the pitch binder.

Perhaps it would pay to add combustion chambers several feet long to the front of locomotive fire boxes, and to use a larger number of shorter and smaller boiler tubes.

The details of these tests may be found in Bureau of Mines Bulletin 34.[b]

Tests on the Chesapeake & Ohio Railway.—In December, 1907, the United States Geological Survey cooperated with the Chesapeake & Ohio Railway Co. in making a series of comparative road tests of run-of-mine coal and briquets of the same coal on a locomotive in regular service. These tests were conducted under the supervision of J. F. Walsh, superintendent of motive power. One car of fuel was used in tests on a passenger locomotive between Old Point and Richmond, Va., and four cars on through express locomotives between Washington, D. C., and Charlottesville, Va. The briquets were made at the fuel-testing plant of the Geological Survey at Norfolk, Va., from run-of-mine coal furnished by the railroad company, with 6 per cent of water-gas pitch used as a binder.

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[a] For sizes and shapes of these briquets see descriptions of these machines.

[b] Ray, W. T., and Kreisinger, Henry, Tests of run-of-mine and briquetted coal in a locomotive boiler. 50 pp., 10 figs. (reprint of U. S. Geol. Survey Bull. 412).

The coal for these tests came from the Fire Creek coal bed at Minden, New River district, West Virginia. The sample consisted of run-of-mine coal and reached the testing plant after having been exposed to the weather 8 to 16 days.

No attempt was made in these tests to make careful measurements of fuel and water; however, during the tests the following facts were developed: The briquets ignited freely, made an intensely hot fire, and emitted very little smoke. It was found that a comparatively heavy fire could be carried without danger of clinkering. Few ashes were left in the fire box or ash pan, and the cinder deposit was small. The results do not show that any apparent improvement in evaporative efficiency was obtained by the use of briquets, as compared with that obtainable from the natural fuel.

Tests on the Atlantic Coast Line Railroad.—W. F. M. Goss, in Bureau of Mines Bulletin 37 [a] gives a synopsis of tests of briquets on the Atlantic Coast Line Railroad. That synopsis is abstracted below.

The results of comparative tests of run-of-mine New River coal and of briquets of the same fuel, made in December, 1907, on a locomotive in the regular passenger service, are presented in the following table. The tests were conducted under the supervision of R. E. Smith, general superintendent of motive power of the railroad, in cooperation with the United States Geological Survey. Sixteen complete test trips were run between Rocky Mount and Wilmington, N. C., with the same engine, crew, and trains. An equal number of tests were made with run-of-mine coal furnished by the railroad company and with round and rectangular briquets made at the Geological Survey fuel-testing plant at Norfolk, Va., with 6 per cent of water-gas pitch binder.

Results of comparative tests of New River coal and of briquets.

Item.	Coal.	Briquets.
Number of test trips	16	16
Total pounds consumed	172,700	161,980
Average pounds consumed per trip	10,794	10,124
Average tons consumed per trip	5.397	5.062
Total engine-miles	1,984	1,984
Total car-miles	10,912	12,896
Pounds consumed per car-mile	15.8	12.5
Average cars per train	5.5	6.5

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[a] Goss, W. F. M., Comparative tests of run-of-mine and briquetted coal on locomotives. 58 pp., 4 pls., 35 figs. (reprint of U. S. Geol. Survey Bull. 363).

It is reported that from a practical standpoint the briquets thus tested were very satisfactory. Their use was found to eliminate all black smoke. No objectionable clinker was formed and the fuel seemed to burn completely.

TESTS ON TORPEDO BOAT "BIDDLE."

The fuel tests conducted at Norfolk included a detailed investigation of a number of Virginia and West Virginia coals that are bought by the United States Government for the Navy and for use in constructing the Panama Canal, and are extensively used by the merchant marine, manufacturing plants, and railroads. Through a cooperative arrangement with the Navy Department, steaming tests of the coals and their briquets were undertaken to determine their relative merits in marine boilers.

The tests were made on board the U. S. torpedo boat *Biddle*, beginning December 6, 1907, and ending January 27, 1908, by W. T. Ray and Henry Kreisinger. The results are reported in Bureau of Mines Bulletin 33.[a]

The coal used in these tests came from the Sewell and Beckley beds in the New River district of West Virginia. With the particular equipment used in the test both coal and briquets were far from smokeless. The possibilities of coals of different composition are indicated by the data to be published later by the Bureau of Mines. A number of tests were made in which only little smoke was emitted while burning raw coal from the Pocahontas No. 3 coal bed, West Virginia, and briquets made therefrom. At a combustion rate of 120 pounds of the Pocahontas briquets per square foot of grate surface there was scarcely any smoke.

The coal used in these tests and in making the briquets was all in run-of-mine form and came from three different mines, all of which are located on the Chesapeake & Ohio Railway and in the New River coal field. These coals are designated Jamestown No. 6[b], Jamestown No. 9[b], and Jamestown No. 11[b]. The briquets were made on the English and Renfrow No. 2 machines at Norfolk, Va.

The main object of these tests was to determine whether the use of briquetted coal on torpedo boats has any advantages over the use of raw coal. Besides comparing the economy obtained with briquetted and raw coal, the following properties of the two fuels were given particular attention: The tendency to smoke; the amount of sparks emitted from the stack; the rate at which steam can be made and the ease with which the fires are handled; and the ease of transferring fuel from the coal bunkers into the fireroom.

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[a] Ray, W. T., and Kreisinger, Henry, Comparative tests of run-of-mine and briquetted coal on the torpedo boat *Biddle*.

[b] See table, p. 41.

In all, 21 tests were made, 10 with run-of-mine coal, 3 with English-machine briquets, and 8 with Renfrow-machine briquets. No test was run with the rate of combustion below 20 pounds per square foot of grate per hour. For the sake of comparison the tests of briquets were made at approximately the same rates of combustion as the tests of the run-of-mine coal of which the respective briquets were made.

Messrs. Ray and Kreisinger, who conducted these tests, give the following conclusions based on the results of the tests and applying only to the tests of New River run-of-mine coals when burned under a boiler of the Normand type and on vessels of the torpedo-boat class.

There is little or no gain in efficiency in burning briquets of either size. Both large and small briquets make as much (or more) smoke as run-of-mine coal. There seems to be more flaming in stack with briquets than with run-of-mine coal. About as many sparks are emitted from the stack whether briquetted or run-of-mine coal is burned. When burning briquets the fire need not be disturbed; with coal the fuel bed has to be broken up, generally after each firing. A somewhat higher boiler capacity can be obtained with briquets than with run-of-mine coal. Steam can be raised more quickly with briquets than with run-of-mine coal. Run-of-mine coal is transferred much more readily than briquets from the coal bunker to the fireroom. With briquets the capacity of a coal bunker is reduced 23 to 27 per cent.

The details of these tests may be found in Bureau of Mines Bulletin 33.[a]

DOMESTIC-FURNACE TESTS.

Briquetted coal has been frequently tested in the hand-fired furnaces under the Heine boilers in the Survey fuel-testing plant at St. Louis. The results were so satisfactory that two series of tests were conducted to determine the value of this fuel for domestic-heating purposes. A number of evaporation tests were made on the house-heating boiler of the structural-materials laboratory, both briquets and coal being used. After these tests were well under way a carload of briquets was shipped to the University of Illinois engineering experiment station at Urbana, Ill., where two house-heating boilers were available. This equipment permitted more uniform conditions of pressure and capacity, making the results more valuable for comparison.

Perhaps the most important result obtained is that showing the relative value of different fuels for domestic purposes. The tests show that with a sectional boiler the effectiveness of different fuels depends on the number of thermal units they contain. One basis for ascertaining the relative value of different fuels lies in the cost of evaporating 1,000 pounds of water. If, for example, at a certain place anthracite costs $8 a ton and Pocahontas bituminous coal $4, the cost of evaporating 1,000 pounds of water with anthracite would be 52 cents and with the bituminous coal 23.68 cents. This shows that a saving of about $4 a ton for the same amount of work done would be effected by purchasing the bituminous coal.

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[a] Ray, W. T., and Kreisinger, Henry, Comparative tests of run-of-mine and briquetted coal on the torpedo boat *Biddle*.

A comparison of results with coal and with briquets shows no advantage in the briquets over coal of a size larger than screened nut. Briquetting good bituminous coal would be justified only when slack is used. The briquets tested gave much smoke, which was due to the pitch used as a binder.

The briquets and coal burned in the tests at St. Louis came from eleven States and Territories. There were 58 tests—11 on raw coals, 34 on round briquets, and 13 on square briquets. Most of the tests were run for about eight hours at a steam pressure of 2 to 3 pounds. The charge of fuel at each firing ranged from 55 to 175 pounds. The interval between firings varied considerably; in some tests coal was fired every half hour, and in others every two hours. The average efficiency in all the tests was 51.48 per cent; it ranged from 38.67 per cent with an Illinois coal to 65.36 per cent with a Virginia coal. The average percentage of builders' rated capacity developed was 59.2; it ranged from 44 per cent with an Illinois coal to 77.2 per cent with an Indian Territory coal. The lowest boiler horsepower developed was 12.1 and the highest 20.6. With the cost of fuel assumed at $1 per 2,000 pounds, the cost of evaporating 1,000 pounds of water from and at 212° F. ranged from 5.56 cents for a briquetted Pennsylvania coal to 11.93 cents for a briquetted Illinois coal. Most of the briquets, whether made from eastern or western coal, smoked badly for several minutes after firing. Of the coals tested raw, six were western and five eastern. The high-volatile western coals smoked badly, but the eastern coals made comparatively little smoke.

An average capacity of 65 per cent was maintained on the 24 briquetting tests at Urbana, the range being from 53.2 to 71.4 per cent. To carry only 65 per cent of the rated radiating surface the draft was wholly or very nearly cut off for one-half to three-fourths of the time. The boiler horsepower developed on boiler A ranged from 4.52 to 4.96 and on boiler B from 4.97 to 6.16. The average efficiency of the boiler and furnace (dry-coal basis) was 44.85 per cent for the 24 tests. A comparison of eight tests of briquets, of which four were made of large briquets and four of small briquets, shows that the large briquets invariably gave an appreciably higher efficiency, indicating that size is an important factor. With the cost of fuel assumed at $1 per 2,000 pounds, the cost of evaporating 1,000 pounds of water from and at 212° F. ranged from 6.74 cents with a Pennsylvania briquet to 12.47 cents with an Illinois briquet. The briquets started readily from a wood fire and burned well, but owing to the difficulty of obtaining complete combustion, the average efficiency from an eight-hour test was low. The formation of soot in the flues of boiler B was more troublesome and affected the economy more than in boiler A. So much soot was formed from partial combustion of the briquets in both boilers that the flues were blown after every test. In two tests the flues of boiler B were completely stopped at the end of the eight-hour run.

DISCUSSION OF RESULTS.

On comparing the results of these tests there seems to be no advantage in the briquets over coal of a suitable size for house-heating boilers. Briquetting a good bituminous coal would be justified only when slack is used and the gain from briquetting would lie almost entirely in the more favorable size of the fuel. This gain would be less for coals that coke readily than for noncoking coals. Briquets made from slack burn fairly well, as they allow the air to pass through the fuel bed.

The experiments showed that the pitch binders used are not suitable for a furnace working at the low temperatures common in a house-heating boiler, as they volatilized and generally escaped unburned or were deposited on the surface of the boiler. In the St. Louis tests this coating burned off once or twice a day, causing a high temperature in the flue and, as a consequence, danger from fire. There was a similar deposit of tarry matter on the boilers at Urbana, but it did not ignite, probably because of the better control of the fire. This deposit reduced the efficiency of the boiler. Briquets with binders that do not volatilize so readily would probably show superior results.

The briquets tested gave off much smoke, owing to the nature of the binder. The results of these tests indicate that coals containing the higher percentages of fixed carbon give the least smoke and the best results for economy.

SPECIAL TESTS.

Certain special combustion tests of briquets were made as described below.

WATER-GAS MACHINE TEST.

The first special test comprised a water-gas machine test. The object of the test was (1) to determine whether briquets could be used as fuel for the production of water gas; (2) to compare the results obtained with those from retort coke; and (3) to observe the behavior of the briquets in the apparatus.

The briquets made in test 164 (Arkansas No. 13) were shipped to the Laclede Gas Co., St. Louis, Mo., and tested in an 8½-foot Lowe water-gas machine. This machine has a rated capacity of 1,000,000 cubic feet in 24 hours. The test was made under the direction of W. A. Baehr, chief engineer of the company.

Results of water-gas machine test of briquets.

Item.	Record.
Length of blast ... minutes..	5
Length of run ... do....	6
Total number of cycles ...	42
Total number of runs made ...	213
Total briquets used ... pounds..	85,100
Total gas recorded by meter in 48 hours ... cubic feet..	1,959,000
Correction for relief holder ... do....	56,100
Total gas made in 48 hours ... do....	1,902,900
Average temperature of gas metered ... ° F..	73
Total gas made in 48 hours corrected to 60° F ... cubic feet..	1,854,000
Total oil used in 48 hours ... gallons..	7,710
Average pressure of air during blast ... inches of water..	22.5
Average steam pressure during runs ... pounds..	29.2
Briquets per 1,000 feet of gas as metered (corrected to 60° F.) ... do....	45.9
Five-hour coke per 1,000 feet of gas as metered (corrected to 60° F.) ... do....	31.5
Oil per 1,000 feet gas as metered (corrected to 60° F.) ... gallons..	4.16
Average luminosity of gas made ... candlepower..	19.4
Average amount of gas made:	
With briquets ... do...	4.65
With 5-hour coke ... do....	5.60
Average heat value of gas made:	
With briquets ... B. t. u..	624
With 5-hour coke ... do....	643
Average yield of gas as metered per run:	
With briquets ... cubic feet..	8,940
With 5-hour coke ... do....	8,450
Average amount of oil per run ... gallons.	36.2

CUPOLA TEST.

The briquets (coke breeze) made in test 247 (see pp. 264, 265) were sent to the Madison plant of the American Car & Foundry Co., of St. Louis, Mo., and were tested in a cupola. The object was to determine whether coke breeze when briquetted could be made to replace coke in foundry practice. It was hoped that by the addition of lime the briquets would be able to support the weight above until they became thoroughly coked.

Coke was used during the first charges and 150 pounds of briquets was used in each of the last five charges. The briquets were considerably broken during the charging of the iron and let the iron down below the melting zone.

COKING OF BRIQUETS AND BRIQUET MIXTURES.

The first experimental attempt to coke briquets was with some of the briquets made from Arkansas No. 4 coal and 6 per cent of pitch B. A box was filled with about 12 crushed briquets and then placed in one of the coke ovens, where it remained during a run of a coking coal. The result of this experiment was a mass of coke that was 12 to 15 inches long and somewhat metallic in appearance.

In the next experiment the box was filled with a mixture of Arkansas No. 4 coal with 6 per cent of pitch B, but without being passed through the press. The mixture was treated in the coke oven similarly to the other, but the results were not so satisfactory as in the first case. The next experiment was with the same mixture briquetted. The briquets were placed in a box and tested in the coke oven in the same manner as the others. The result of this test was masses of coke that retained the form of the original briquet. All of the coke obtained by these experiments, although not of the quality desired for iron smelting, could be used for lead and copper smelting.

Another experiment on a larger scale was with two tons of Arkansas No. 6 slack coal. This coal was mixed with 8 per cent of pitch A and then ground in the Williams mill and charged into a coke oven, together with an equal weight of the same mixture that had been previously briquetted. Both mixtures made coke, but not of the best quality. The experiments seemed to show that although a coke can be made by mixing coal and pitch a better quality is obtained by previously briquetting the mixture; however, sufficient experiments along this line have not yet been made to justify any definite conclusions.

DETAILS OF BRIQUETTING TESTS.

The data obtained from the general briquetting tests at the several experiment stations are presented below.

ALABAMA NO. 1.

Briquetting tests were made of a sample of bituminous coal (over 1-inch screen) from a mine 1½ miles west of Horse Creek, Walker County, on the Frisco system. The tests were conducted at the St. Louis plant.

This is a coking coal which can be readily briquetted with hard pitch and, under extreme pressure, can be briquetted without the addition of any binder. There was 4.5 tons of this coal briquetted on the English machine with 7 per cent of the hard pitch A. The briquets were strong and rather satisfactory, except for porosity due to a lack of sufficient pressure. The briquets stand up well in the fire, but on long exposure to the weather disintegrate somewhat. The weight of the briquets averaged 5⅛ pounds each.

Chemical analyses of coal and briquets.

	Car sample.	Briquets.
Laboratory No.	1201	1194
Proximate:		
Air-drying loss ... per cent..	0.80	1.20
Moisture ... do....	2.34	2.63
Volatile matter ... do....	31.84	33.00
Fixed carbon ... do....	53.28	50.96
Ash ... do....	12.54	13.41
Sulphur ... do....	.72	.94
Ultimate:		
Hydrogen ... do....	4.86	4.71
Carbon ... do....	73.30	72.65
Nitrogen ... do....	1.69	1.42
Oxygen ... do....	6.57	6.49
Heat value ... B. t. u..	12,856	12,755

ALABAMA NO. 2B.

Seven tons of bituminous coal from Carbon Hill, Walker County, on the Frisco system, was used in tests 131.1 to 131.4. Steaming test 410 was conducted with the briquets made from this fuel. The English briquets with 5 and 6 per cent of binder were good briquets; fracture clean; edges and surfaces firmer with 6 per cent than with 5 per cent binder. The Renfrow briquets made with 6 per cent of pitch showed evidence of shortage of binder; surfaces crumbled and fracture not clean. Seven per cent of binder made briquets with hard, firm surfaces; they broke without crumbling.

Briquetting tests.

	Test. No.			
	131.1.	131.2.	131.3.	131.4.
Size as shipped ...	r. o. m.	r. o. m.	r. o. m.	r. o. m.
Size as used:				
Over $\frac{1}{4}$ inch ... per cent..	2.8	2.8	2.8	2.8
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch ... do....	11.6	11.6	11.6	11.6
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch ... do....	21.2	21.2	21.2	21.2
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch ... do....	23.4	23.4	23.4	23.4
Through $\frac{1}{40}$ inch ... do....	41.0	41.0	41.0	41.0
Details of manufacture:				
Machine used ...	English.	English.	Renfrow No. 1.	Renfrow No. 1.
Briquetting temperature ... °F..	175	175	149	149
Binder—				
Kind ...	W. G. P.	W. G. P.	W. G. P.	W. G. P.
Laboratory No. ...	3410	3410	3410	3410
Amount ... per cent..	5	6	6	7
Weight of—				
Fuel briquetted ... pounds..	(a)	(a)	(a)	(a)
Briquet, average ... do....	3.31	3.31	0.47	0.47
Drop test (1-inch screen):				
Held ... per cent..	91.5	...	...	...
Passed ... do....	8.5	...	...	...
Weather test:				
Time exposed ... days..	197	...	201	200
Condition ...	B	...	B	B

[a] Total weight of fuel briquetted, 14,000 pounds.

Chemical analyses of coal and briquets.

	Car sample.	Test 131.[a]
Laboratory No.	3211	....
Proximate:		
Moisture per cent.	3.95	3.43
Volatile matter do.	30.70	32.74
Fixed carbon do.	50.76	51.34
Ash do.	14.59	12.49
Sulphur do.	1.12	1.24
Ultimate:		
Hydrogen	4.30	4.77
Carbon do.	68.94	72.17
Nitrogen do.	1.55	1.58
Oxygen do.	8.85	7.27

[a] Composite sample of briquets from several lots.

Extraction analyses.

	Pitch.	Fuel.	Briquet.
		A-2B.	Test 131.
Laboratory No.	3410	3211	....
Air-drying loss per cent.	....	1.70	....
Extracted by CS_2 (as received) do.	79.98	1.35	4.75
Pitch in briquet by analysis do.	....	....	4.32
Heat value B. t. u.	16,478	11,785	12,115

ALABAMA NO. 4.

Seven and one-half tons of bituminous coal from Cane Creek, 3 miles north of Belle Ellen, Bibb County, on the Louisville & Nashville Railroad, was used in briquetting tests 123A to 123H. Steaming test 413 was conducted with the briquetted fuel.

English briquets with 5.5 per cent of binder had edges that crumbled slightly, but the surfaces were firm; fracture slightly crumbly. With 6, 6.5, and 7 per cent binder the outer surfaces were smooth and hard, fracture clean, and broken surfaces rough but very firm.

Renfrow briquets made with 6 and 6.5 per cent binder crumbled easily, and broken surfaces were crumbly. With 7 and 7.5 per cent of binder tough briquets resulted, with hard and smooth outer surfaces; the briquets broke with clean fracture.

Briquetting tests.

	Test No.							
	123A.	123B.	123C.	123D.	123E.	123F.	123G.	123H.
Size as shipped	r. o. m.	r. o. m.	r. o. m.	r. o. m.	r. o. m.			
Size as used:								
Over $\frac{1}{4}$ inch, per cent	1.2							
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch, per cent	4.5							
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch, per cent	14.0							
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch, per cent	23.5							
Through $\frac{1}{40}$ inch, per cent	56.8							
Details of manufacture:								
Machine used	English.	English.	English.	English.	Renfrow No. 1.	Renfrow No. 1.	Renfrow No. 1.	Renfrow No. 1.
Briquetting temperature...°F.	179.6	179.6	179.6	179.6	149	149	149	149
Binder—								
Kind	W. G. P.	W. G. P.	W. G. P.	W. G. P.	W. G. P.	W. G. P.	W. G. P.	W. G. P.
Laboratory No.	3410	3410	3410	3410	3410	3410	3410	3410
Amount, per cent	5.5	6	6.5	7.0	6	6.5	7.0	7.5
Average weight of briquet, pounds	3.37	3.37	3.37	3.37	0.43	0.43	0.43	0.43
Drop test (1-inch screen):								
Held...per cent		83.3						
Passed.....do		16.7						
Weather test:								
Time exposed, days	214	214	214	214	214	214	214	214
Condition	B	B	B	B	C	C	C	B

Chemical analyses of coal and briquets.

	Car sample.	Test 123.
Laboratory No.	3103	
Proximate:		
Moisture...per cent	6.43	2.46
Volatile matter...do	28.56	32.27
Fixed carbon...do	52.09	56.55
Ash...do	12.92	8.72
Sulphur...do	1.08	1.18
Ultimate:		
Hydrogen...do	4.83	4.72
Carbon...do	73.82	76.96
Nitrogen...do	1.26	1.32
Oxygen...do	5.13	6.85

Extraction analyses.

	Pitch.	Fuel.	Briquets.
		Ala. No. 4.	Test 123.
Laboratory No.	3410	3103	
Air-drying loss...per cent		5.50	
Extracted by CS_2 (as received)...do	79.98	.43	4.86
Pitch in briquet by analysis...do			5.57
Heat value...B. t. u.	16,478	12,395	13,590

ARGENTINA NO. 1.

Coal received from the Province of Mendoza, Argentina, South America, was designated Argentina No. 1. Steaming test 485 was made of the briquetted fuel.

Renfrow briquets made with 7 per cent of pitch binder were very heavy and hard and gave a rough fracture without crumbling when broken. The coal particles were firmly cemented, and the briquets could be handled when warm without breaking. The sample of run-of-mine fuel used for the briquetting test was washed.

Chemical analyses of coal and briquets.

	Car sample.	Test 180.
Laboratory No.	4079	
Proximate:		
Moisture per cent	7.67	8.75
Volatile matter do	18.39	21.45
Fixed carbon do	31.09	33.75
Ash do	42.85	36.05
Sulphur do	1.21	.80
Ultimate:		
Hydrogen do	2.76	3.41
Carbon do	39.59	47.51
Nitrogen do	1.03	.92
Oxygen do	8.90	7.77

Extraction analyses.

	Pitch.	Fuel.	Briquets.
		Argentina No. 1.	Test 180.
Laboratory No.	4543	4079	
Air-drying loss per cent		3.0	4.30
Extracted by CS_2 (as received) do	99.66	.06	6.10
Pitch in briquet by analysis do			6.06
Heat value B. t. u.	16,969	6,320	7,515

Briquetting test.

	Test 180.		Test 180.
Size as shipped	r. o. m.	Drop test (1-inch screen):	
Size as used:		Held per cent	84.5
Over 1/4 inch per cent	3.0	Passed do	15.5
1/10 inch to 1/4 inch do	8.4	Tumbler test (1-inch screen):	
1/20 inch to 1/10 inch do	15.0	Held do	91.2
1/40 inch to 1/20 inch do	19.2	Passed do	8.8
Through 1/40 inch do	54.4	Fines through 10-mesh sieve, per cent	94.0
Details of manufacture:			
Machine used	Renfrow No. 1	Weather test:	
Briquetting temperature °F	185	Time exposed days	19
Binder:		Condition	A
Kind	W. G. P.	Absorption test:	
Laboratory No.	4543	Time immersed days	19
Amount per cent	7	Water absorbed per cent	9.8
Weight of—		Average for first 4 days do	1.44
Fuel briquetted pounds	6.000	Specific gravity (apparent)	1.467
Briquet, average do	0.603		

ARKANSAS NO. 1.

A sample of semibituminous coal (over 1⅛-inch screen) from Huntington, Sebastian County, on the Frisco system, was designated Arkansas No. 1, and briquetting tests of a portion of the sample were made at the St. Louis plant.

This coal was tested only with hard pitch A, as this was the only pitch available at the time the coal was briquetted. Six tons of coal was mixed with 9.25 per cent of this pitch and made into briquets on the English machine. The briquets were compact, but were too friable for handling, showing that they contained insufficient pitch. They were brownish and dirty. Judging from the results obtained in working with other Arkansas coals, this coal will require more than the usual proportion of pitch.

Although the actual steaming test of these briquets was satisfactory as compared with the tests of the coal, yet the briquets could not be considered a commercial product on account of their friability.

Chemical analyses of coal and briquets.

	Car sample.	Briquets.
Laboratory No	1114	....
Proximate:		
Air-drying loss......per cent..	2.10	....
Moisture......do....	3.24	0.94
Volatile matter......do....	17.46	21.21
Fixed carbon......do....	66.69	67.65
Ash......do....	12.61	10.20
Sulphur......do....	1.24	1.73
Ultimate:		
Hydrogen......do....	3.92	3.91
Carbon......do....	76.57	79.76
Nitrogen......do....	1.49	1.58
Oxygen......do....	3.71	2.70
Heat value......B. t. u..	13,129	13,707

ARKANSAS NO. 2.

A sample of semibituminous coal (over 1⅛-inch screen) from Bonanza, Sebastian County, on the Frisco system, was designated Arkansas No. 2. A part of the sample was subjected to briquetting tests at the St. Louis plant.

This coal was tested with the hard pitch X, which at the time was the only pitch available. The briquets were made in the English machine. Six tons of crushed lump coal was run through the machine, with approximately 11 per of cent pitch. The briquets were pitchy and wrinkled and probably contained nearer 15 per cent than 11 per cent of pitch. On account of the difficulty of setting the machine to feed accurate proportions of pitch and coal, the later experiments were conducted by weighing the desired quantities of binder. Pitch X, on account of its hardness, set too quickly in the molds, so that the briquets were insufficiently pressed and consequently porous.

Although they were not commercial briquets, a steaming test was made with them. The greater percentage of volatile matter in the briquets is due to the large proportion of pitch used in them.

Chemical analyses of coal and briquets.

	Car sample.	Briquets.
Laboratory No	1160	1112
Proximate:		
Air-drying loss ... per cent..	1.50	4.00
Moisture ... do....	2.23	4.88
Volatile matter ... do....	16.02	22.49
Fixed carbon ... do....	72.55	60.30
Ash ... do....	9.20	12.33
Sulphur ... do....	1.87	1.32
Ultimate:		
Hydrogen ... do....	4.08	4.06
Carbon ... do....	80.63	76.65
Nitrogen ... do....	1.41	1.54
Oxygen ... do....	2.56	3.40
Heat value ... B. t. u..	13,750	12,915

ARKANSAS NO. 3.

A sample of semibituminous coal (over 1⅛-inch screen) from Jenny Lind, Sebastian County, on the Missouri Pacific Railroad, was designated Arkansas No. 3, and a part of the sample was subjected to briquetting tests at the St. Louis plant.

This coal was briquetted with 9.5 per cent of the hard pitch X. The coal was slightly moist, and passed through the machine without clogging the elevator. As the coal was friable it was reduced almost to a flour in the disintegrator. The briquets had smooth, polished surfaces. Some of the briquets as delivered by the machine showed cracks, perpendicular to the pressure, which may have been due to an excess of moisture. The briquets weighed on an average 6.8 pounds each.

The coal was also tested with the somewhat softer pitch A. One ton of the coal was mixed with 8.7 per cent of pitch. A large excess of steam was introduced into the pug mill so as to soften the pitch as much as possible. The briquets were smooth and easily handled, but pitchy. Under the same conditions of heat and pressure, 7.5 per cent of pitch A would have been sufficient, and if pitch of proper grade were used a still smaller amount would make a good commercial briquet. These briquets ignited readily and did not disintegrate in the fire.

Chemical analyses of coal and briquets.

	Car sample.	Briquets.
Laboratory No.	1296	1293
Proximate:		
Air-drying loss ... per cent.	1.40	1.60
Moisture ... do.	2.19	2.60
Volatile matter ... do.	19.47	17.35
Fixed carbon ... do.	66.71	62.04
Ash ... do.	11.63	18.01
Sulphur ... do.	1.28	1.41
Ultimate:		
Hydrogen ... do.	4.02	3.46
Carbon ... do.	77.00	72.47
Nitrogen ... do.	1.56	1.42
Oxygen ... do.	4.22	2.72
Heat value ... B. t. u.	13,464	12,357

ARKANSAS NO. 4.

A sample of semibituminous slack coal from Denning, Franklin County, on the Missouri Pacific Railroad, was designated Arkansas No. 4. A part of the sample was subjected to briquetting tests at the St. Louis plant.

The sample consisted of slack coal, which was so saturated with water when received that it had to be dried before it could be used. When dried it was so brittle that the disintegrators of the English machine reduced it to flour, which choked the elevator and other parts of the machine. The first run made with this coal contained 12 per cent of hard pitch X, and although the briquets when first received from the machine were compact and smooth, they were unsatisfactory, and on exposure to the weather became friable and soon began to disintegrate. The next test of this finely divided coal was with pitch A. One ton was mixed with 10 per cent of pitch. The press was run faster, not only to increase the pressure, but also to give the hard pitch less time to set in the machine. At the same time the speed of the disintegrator was reduced in order not to pulverize the coal so completely. The briquets were pitchy, and, owing to the excess of water from condensation, many cracked when the pressure was relieved. Another ton of coal with 8 per cent of pitch A was used, but found to contain too much binder; still another ton was made into briquets with 6 per cent of pitch. The latter briquets were compact, but did not contain enough binder. Seven per cent of pitch A gave a better result than either 6 or 8 per cent.

Another run of this coal was made with 3 per cent of rosin and 2 per cent of pitch A. The briquets were clean and sharp, but were somewhat brittle and had a tendency to break into large fragments. They were, however, physically better than those with 6 or 8 per cent of pitch alone. In burning, they held together well but smoked more than those with pitch alone. No odor of rosin was given off, however. The same mixture was tested on the American machine, which gave clean, polished briquets. They were stronger than those made on the English machine, indicating that rosin works to better advantage in the smaller and more rounded briquets. With pitch alone, however, and Arkansas No. 4 coal, a stronger briquet was made on the English machine than on the American. The weight of the briquets made with the rosin averaged 6.87 pounds each.

One ton of this coal was briquetted with 3 per cent of rosin and 3 per cent of pitch A. The mixture made excellent briquets, which were unusually clean and had sharp edges. They weighed 6.87 pounds each. This mixture was also tried on the American machine and gave exceedingly smooth and lustrous eggettes, which were stronger than the large briquets made on the English machine. Although no boiler test was made of the eggettes, some of them were thrown under the boiler, where they burned very readily without disintegration. They were tested in a cook stove, where they burned satisfactorily without any odor, but gave off considerably more smoke than either coal or briquets made from pitch alone as a binder. The specific gravity of these briquets was 1.13, whereas the specific gravity of the coal was 1.35. Their compression or crushing strength was 8,780 pounds, or 306 pounds per square inch.

The Arkansas No. 4 coal was further tested with the softer pitch B, which was one of the better pitches for briquetting. One ton was briquetted with 6 per cent of pitch. The briquets were clean and seemingly considerably stronger than the original lump coal and were capable of standing rough handling. They averaged 7 pounds each, and their specific gravity was 1.17. On the American machine the mixture gave polished eggettes, but these were not so strong as those made on the English machine.

Pitch B was then tried with rosin, the proportions being 95 per cent coal, 3 per cent rosin, and 2 per cent pitch. On account of the condensation of steam in the pug mill, there was considerable excess of water in the briquets, which, however, were smooth and sharp. The excess of moisture caused them to crack badly and they were difficult to handle while fresh. After cooling, they were still soft, and they were noticeably inferior to the briquets made with 3 per cent of rosin and 2 per cent of pitch A. They weighed 7.2 pounds each. The mixture was tested also on the American machine, which made harder eggettes than the corresponding briquets of the English machine. The smaller and rounder form is better adapted for the rosin binder and will result in a harder and tougher briquet.

Six tons of this coal was briquetted with 6 per cent of pitch B, in order to make a steaming test. Some of the briquets were made by running one side of the disintegrator of the English machine, and as they were received from the machine they were smooth and uniform, but soft. On cooling, the briquets became hard and tough.

Another ton was briquetted with both sides of the disintegrator running, which made smooth, uniform briquets, but it was almost impossible to handle them as they came from the machine. Therefore, only one side of the disintegrator was used, but the materials were run through the pug mill more rapidly and better results were obtained All of these briquets were excellent in every respect. When these mixtures were tried on the American machine, the fine material made better eggettes than the corresponding briquets of the English machine, whereas the coarser material did not make as good eggettes as briquets. The weight of the briquets obtained with both sides of the disintegrator running was 6.92 pounds each; the coarser briquets weighed 6.56 pounds each. The specific gravity of the briquets was 1.17 and their crushing strength was 17,500 pounds, or 610 pounds per square inch.

Chemical analyses of coal and briquets.

	Raw fuel.	English briquets.	American briquets.
Laboratory No		1320	1335
Proximate:			
Air-drying loss per cent		2.10	0.10
Moisture do	1.28	3.85	3.18
Volatile matter do	12.82	14.06	18.60
Fixed carbon do	73.69	71.98	66.03
Ash do	12.21	10.11	12.19
Sulphur do		1.65	1.70
Ultimate:			
Hydrogen do		3.50	3.93
Carbon do		80.89	78.31
Nitrogen do		1.42	1.32
Oxygen do		1.96	2.10
Heat value B. t. u		13,414	13,464

ARKANSAS NO. 5.

A sample of semibituminous coal (half lump and half slack) from west of Coal Hill, Franklin County, on the Missouri Pacific Railroad, was designated Arkansas No. 5. A part of the sample was subjected to briquetting tests.

On account of the success obtained with the other Arkansas coals and the softer pitches, it was decided to make a sufficient quantity of briquets for a locomotive test on the Missouri Pacific Railway. For this purpose 17 tons of Arkansas No. 5 coal was briquetted with 6 per cent of pitch C. Excellent briquets were obtained, which were readily handled while warm, and on cooling stood a good deal of rough handling. They did not break so readily as the original lumps of coal. The briquets were tested on a locomotive of the Missouri Pacific Railway Co., and for comparison similar runs were made of an Illinois run-of-mine coal such as is commonly used on these locomotives. Three trips were made from St. Louis to Washington, Mo., and return, a total run of 324 miles for each fuel. The results of the three runs are given in the following table:

Locomotive tests of briquets of Arkansas No. 5 coal.

Briquets consumed.	Ash removed.	Front end cinders removed.	Total coal consumed.	Total ash removed.	Ash.	Miles to ton.
Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	
9,720	1,250	194	29,594	4,615	15	21.89
10,049	1,535	182				
9,825	1,226	228				

Locomotive tests of run-of-mine Illinois coal.

Coal consumed.	Ash removed.	Front end cinders removed.	Total coal consumed.	Total ash removed.	Ash.	Miles to ton.
Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	
11,265	1,980	130	34,015	5,695	16.4	19.05
11,050	1,558	112				
11,700	1,800	115				

The Arkansas briquets gave better results than the Illinois coal, indicating that by briquetting even an inferior coal it is possible to obtain a fuel that is superior not only to the original coal, but to good coals. L. Bartlett, one of the master mechanics of the Missouri Pacific Railway Co., under whose general direction these tests were conducted, says that "the briquets are too large for locomotive use. They must be thrown indiscriminately into the fire boxes, and if they take position side by side, the flame can not reach them. If, on the other hand, they lie in irregular positions, the spaces may be too large, resulting in a bad effect by allowing too much cold air to pass. In fact, the engine does not steam well until they are broken."

The briquets have always been considered too large, and in all steaming tests at the testing plant they were broken before the furnace was fed, and tests were made of the briquets to determine the amount of fine dust they made when broken.

Mr. Bartlett also noted the amount of smoke given off by this coal and stated that one advantage of the briquetted fuel was that it could be called a smokeless fuel as compared with the Illinois coal. This advantage would, of course, be considerable on switching engines in city freight yards.

The sulphur content of this coal, and consequently of the briquets, is rather high. The sulphur naturally attacked the grate bars, so that the briquets had a more injurious effect on the grate bars than coals containing less sulphur.

A further test of Arkansas No. 5 coal was made by mixing one-fourth of the soft pitch C and three-fourths of the hard pitch A, a combination that made a good briquet, but not so good as that made with 6 per cent of pitch C. With more than three-fourths of hard pitch, it was necessary to use more steam for heating and greater pressure, and the resultant briquets were considerably inferior and more crumbly.

Chemical analysis.

	Car sample.		Car sample.
Laboratory No.	1331	Ultimate:	
Proximate:		Hydrogen........per cent..	3.65
Air-drying loss........per cent..	1.10	Carbon........do....	78.29
Moisture........do....	2.36	Nitrogen........do....	1.40
Volatile matter........do....	12.68	Oxygen........do....	2.25
Fixed carbon........do....	72.88	Heat value........B. t. u..	13,259
Ash........do....	12.08		
Sulphur........do....	1.99		

ARKANSAS NO. 6.

A sample of bituminous slack coal from Jenny Lind, Sebastian County, on the Missouri Pacific Railroad, was designated Arkansas No. 6. This coal was briquetted with 8 per cent of pitch A and made a briquet of fair quality. The briquets were made in order to test the coking value of the mixture, and the results are described under "Coking of Briquet Mixtures."

Proximate analysis.

	Car sample.		Car sample.
Laboratory No.	1542	Proximate—Continued.	
Proximate:		Fixed carbon........per cent..	68.50
Air-drying loss........per cent..	3.00	Ash........do....	13.81
Moisture........do....	3.80	Sulphur........do....	1.26
Volatile matter........do....	13.89		

ARKANSAS NO. 7B.

Semibituminous slack coal from a mine 4 miles southwest of Midland, Sebastian County, on the Midland Valley Railroad, was designated Arkansas No. 7B. Briquets were made of 4,000 pounds of this washed slack coal.

English briquets made with 4, 5, and 6 per cent of binder were equally satisfactory, with hard, fine structure, glossy fracture, and well-molded, sharp edges.

Briquetting tests.

	Test 106.1.	Test 106.2.	Test 106.3.
Details in manufacture:			
Machine used	English.	English.	English.
Briquetting temperature °F.	179.6	179.6	179.6
Binder—			
Kind	C. T. P.	C. T. P.	C. T. P.
Laboratory No	2735	2735	2735
Amount per cent.	4	5	6
Drop test (1-inch screen):			
Held do.	31.4	....	....
Passed do.	68.6	....	....
Weather test:			
Time exposed days.	80	80	80
Condition	C	B	B

Chemical analysis.

	Car sample.		Car sample.
Laboratory No	2722	Ultimate:	
Proximate:		Hydrogen per cent.	3.94
Moisture per cent.	6.89	Carbon do.	73.33
Volatile matter do.	15.23	Nitrogen do.	1.35
Fixed carbon do.	62.88	Oxygen do.	2.86
Ash do.	15.00		
Sulphur do.	2.24		

Extraction analyses.

	Pitch.	Fuel.
		Ark. No. 7B.
Laboratory No	....	2722
Air-drying loss per cent.	....	5.90
Extracted by CS_2 (as received) do.	58.56	....
Heat value B. t. u.	....	12,060

ARKANSAS NO. 13.

Bituminous slack from the mines at Denning on the St. Louis, Iron Mountain & Southern Railway was designated Arkansas No. 13. No steaming tests were made of this fuel either in the natural or briquetted form.

There was no noticeable difference in appearance between briquets made with 7 and 8 per cent of binder. Both were excellent, with hard, smooth surface and clean fracture, and were easily handled and piled while warm. Less binder could be used with increased pressure. The briquets with 8 per cent of binder made less slack in handling when cold. Those with 9 per cent were not satisfactory, as the pitch used had a much higher melting point and could not be successfully worked with the pressure available. Briquets from test 164 were used in the test of briquets in a water-gas machine. (See "Miscellaneous Tests of Briquets.")

Briquetting tests.

	Test 164.	Test 214.	Test 221.
Size as shipped	Slack.	Slack.	Slack.
Size as used:			
Over $\frac{1}{4}$ inch ... per cent	1.4	1.4	1.4
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch ... do	6.2	6.2	6.2
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch ... do	10.6	10.6	10.6
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch ... do	15.8	15.8	15.8
Through $\frac{1}{40}$ inch ... do	66.0	66.0	66.0
Details of manufacture:			
Machine used	Renfrow No. 1.	Renfrow No. 1.	Renfrow No. 1.
Briquetting temperature ... °F	185	185	185
Binder—			
Kind	W. G. P.	W. G. P.	W. G. P.
Laboratory No	3885	3885 4683	4625
Amount ... per cent	7	8	9
Weight of—			
Fuel briquetted ... pounds	140,000	40,000	5,000
Briquet, average ... do	0.451	0.464	0.489
Drop test (1-inch screen):			
Held ... per cent	54.5	49.5	51.0
Passed ... do	45.5	50.5	49.0
Tumbler test (1-inch screen):			
Held ... do	79.0	81.5	86.0
Passed ... do	21.0	18.5	14.0
Fines through 10-mesh sieve ... do	87.7	87.3	88.9
Weather test:			
Time exposed ... days	106	....	....
Condition	B	....	....
Absorption test:			
Time immersed ... days	19	13	13
Water absorbed ... per cent	17.2	13.6	10.2
Average for first 4 days ... do	2.50	2.36	1.72
Specific gravity (apparent)	1.130	1.161	1.247

Chemical analyses of coal and briquets.

	Car sample.	Test 164.	Test 214.	Test 221.
Laboratory No	3798	4892	....	4626
Proximate:				
Moisture ... per cent	2.91	1.49	1.05	1.76
Volatile matter ... do	12.65	15.11	16.50	15.98
Fixed carbon ... do	66.93	68.30	68.84	67.30
Ash ... do	17.51	15.10	13.61	14.96
Sulphur ... do	3.12	2.58	2.48	2.29
Ultimate:				
Hydrogen ... do	3.38	3.84	3.85	3.84
Carbon ... do	73.01	75.03	75.63	75.65
Nitrogen ... do	1.21	1.35	1.24	1.24
Oxygen ... do	1.15	1.83	1.70	1.71

Extraction analyses.

	Pitches.			Fuel.	Briquets.		
				Ark. No. 13.	Test 164.	Test 214.	Test 221.
Laboratory No	3885	4625	4683	3798	4892	....	4626
Air-drying loss ... per cent	....	....	....	1.70	0.70	....	0.80
Extracted by CS_2 (as received) ... per cent	95.20	90.56	89.31	.09	5.76	6.29	6.29
Pitch in briquet by analysis ... per cent	....	....	....	....	5.97	6.63	6.63
Heat value ... B. t. u.	16,870	16,576	16,637	12,312	12,917	12,926	12,926

CALIFORNIA COAL—PITTSBURGH NO. 14.

A 3-car sample lot of run-of-mine lignite from the Ione mine, at Ione, Amador County, Cal., was designated Pittsburgh No. 14.

Briquetting tests 308, 309, 310, 311, 313, 314, 315, and 329 were made on it with the German lignite press. Gas-producer test 185 and house heating boiler test H90 were made on the raw lignite, and gas-producer test 188 and house-heating boiler tests H88 and H89 were made on the briquets.

The color of this lignite was light brown. It had a peculiar waxy feeling, like that of soapstone, and could be easily polished. A casual inspection showed that the lignite was rich in binding material. The results of subsequent tests and analyses confirmed this fact.

In the first test (308) of this lignite, the press operated much more easily than in the tests of Texas and North Dakota lignites. The dried material contained about 9.75 per cent moisture and the dies were set to give a high pressure. The briquets had rough surfaces, especially at the edges, but were of good shape. The cohesion test showed them to be stronger than the briquets made from any other lignite; in fact, they were surpassed in strength only by those made from the same lignite in test 329.

In test 309 the briquets were of excellent shape as they left the press, but on slight handling most of them broke in two along a shearing plane that extended diagonally from one long edge to another. Investigation indicated that this weakness resulted from the material being too dry to flow perfectly in the mold. In the next test (310) the moisture content of the briquet mixture was 1 per cent higher (8½ per cent) and the shearing was practically eliminated, although there were some signs of it. On account of this defect none of the briquets from tests 309 and 310 was saved.

Test 311 was made to see whether weathering injured the briquetting qualities of this lignite. The material used had been spread on the ground for 22 days and had become fine slack. In comparison with the car sample the only change shown by proximate analysis was a smaller percentage of moisture. Seemingly the weathering did not affect the briquetting qualities at all, for the test produced briquets having satisfactory shape, surface, and strength.

In test 313 the moisture in the briquet material was a little over 9 per cent, and a set of dies, ground to give a very heavy pressure, was used. The briquets were the weakest of any made from this lignite. Their lack of strength may have resulted in part from the dies being new, as dies work better after being polished by use.

Tests 314 and 315 were made to determine whether better briquets could be obtained by passing the undried material through a screen having $\frac{5}{16}$-inch openings. The undried material for test 314 was not screened, but that for test 315 was screened. With the same steam pressure in the drier, the dried material contained 14.6 per cent moisture in test 314 and only 10.13 per cent in test 315. The two lots of briquets had satisfactory strength, but both the drop and the tumbler tests showed that the screened material made the stronger briquets, the gain in strength being 12 per cent by the drop test and 26 per cent by the tumbler test. The two lots, however, did not differ much in general appearance, both being well formed and smooth.

Test 329 furnished the best lot of briquets made from this lignite. There was 10 per cent moisture in the briquet material; the pressure used was high, but lower than in tests 313, 314, and 315. The briquets had well-polished surfaces, and were the strongest made from any of the lignites named in this report. A "cohesive strength" of 71 per cent was shown by the drop test and 68 per cent by the tumbler test.

This lignite briquets very easily, as it contains more than enough natural binder. Excellent briquets were made with the German press by drying the ground lignite till it contained from $8\frac{1}{2}$ to 15 per cent moisture. The best briquets will be obtained when the material is ground so that all of it passes a $\frac{1}{4}$-inch screen and 40 per cent passes a $\frac{1}{20}$-inch screen, the briquets being subjected to a moderately high pressure. An extremely high pressure does not give the best results and increases the cost. The right pressure can be had by using a set of dies so ground that the tangent of the die angle is 6/89.

Summary of tests.

Test No.	Moisture in briquet material.	Pressure in mold.	Character of briquets.		Remarks.
			Form.	Strength.	
	Per cent.				
308	9.74	High	Good	Very good	Sides slightly cracked.
309	7.78	do	Excellent	Weak	Sheared diagonally.
310	8.51	do	Good	Good	No shearing evident.
311	7.68	do	do	do	Material too dry.
313	9.14	Very high	do	Fair	Do.
314	14.61	do	Very good	Very good	
315	10.13	do	do	do	
329	10.00	High	Excellent	Excellent	

Mixtures of this lignite with 25 and with 50 per cent of a Pittsburgh coal made excellent briquets. Patents have been granted for utilizing the natural binder of certain lignites to briquet mixtures of these lignites with bituminous-coal slack. Anthracite screenings can be used in place of the bituminous slack, and the substitution of such screenings would lessen the production of smoke.

Preliminary results from gas-producer tests of raw and briquetted samples of this lignite showed that the consumption of fuel, as fired per hour per brake horsepower developed, was 4.06 pounds for the raw lignite and only 2.84 pounds for the briquets. The relative efficiency of the raw and the briquetted lignite as boiler fuel was roughly shown by house heating boiler tests H88, H89, and H90. Each pound of raw lignite evaporated 2.82 pounds of water at 212° F., and each pound of briquets evaporated 3.23 pounds.

The briquets resisted weathering well. Weathering does not entirely destroy the briquetting qualities of this lignite, as shown by the results of a test made on a sample that had been exposed to the weather for two years. It briquetted well, without addition of binder, under a pressure of only 6,000 pounds per square inch, after the sample had been dried and then heated by a steam jet for one minute.

Briquetting tests.

	Test No.							
	308.	309.	310.	311.	313.	314.	315.	329.
Size as shipped	r. o. m.	r. o. m.	r. o. m.	r. o. m.	r. o. m.	r. o. m.	r. o. m.	r. o. m.
Size as used:								
Over $\frac{1}{4}$ inch, per cent	2.0	3.5	2.0	2.0	6.5	10.0	5.0	3.0
$\frac{1}{10}$ to $\frac{1}{4}$ inch, per cent	18.5	21.0	18.5	18.5	29.0	33.0	29.0	29.0
$\frac{1}{20}$ to $\frac{1}{10}$ inch, per cent	31.0	33.0	29.0	32.5	23.0	21.5	23.5	26.0
$\frac{1}{40}$ to $\frac{1}{20}$ inch, per cent	23.5	24.0	24.5	22.5	17.5	14.5	18.5	18.0
Through $\frac{1}{40}$ inch, per cent	25.0	18.5	26.0	24.5	24.0	21.0	24.0	24.0
Details of manufacture:								
Machine used	German.	German.	German.	German.	German.	German.	German.	German.
Briquetting temperature, ° F	102	95	86	91	92	104	95	107
Binder used	None.	None.	None.	None.	None.	None.	None.	None.
Tangent of die, angle	6/89	6/89	6/89	6/89	7/89	7/89	7/89	6/89
Steam pressure on drier, pounds	10	15	13	10	10	5	5	7
Weight of—								
Fuel briquetted, pounds	6,875	[a] 1,790	2,457	3,407	2,915	13,937	8,304	9,000
Briquets, average, pounds	0.88	0.85	0.90	0.86	....	1.05	1.02	0.92
Moisture in briquet mixture, per cent	9.74	7.78	8.51	7.68	9.14	14.61	10.13	10
Drop test, 1-inch screen:								
Held...per cent	68	(a)	....	52	28.00	50	62	71
Passed.....do	32	(a)	....	48	72.00	50	38	29
Tumbler test, 1-inch screen:								
Held...per cent	68	(a)	....	48	....	38	64	68
Passed.....do	32	(a)	....	52	....	62	36	32
Fines through 10-mesh sieve, per cent	63.5	(a)	....	65.5	....	40	45.5	58.5
Weather test:								
Time exposed, days	66	....	....	66	66	66	66	66
Condition	A	....	....	A	B	A	A	A

[a] Briquets scrapped on account of diagonal cracks in them.

The tables following show the changes in composition of this fuel during storage at the plant for 68 days, until used for the last briquetting test. The average of proximate analyses of 8 samples used for tests on different dates is also given. No mine sample was taken.

Chemical analyses.

	Car sample.	Sample as used on last test.	Average of 8 samples.
Date taken	Apr. 22	June 29	....
Laboratory No	7621	8019	....
Proximate:			
Air-drying loss ... per cent..	32.30	22.7[illegible]	26.09
Moisture ... do....	39.46	27.97	34.52
Volatile matter ... do....	29.50	34.54	33.84
Fixed carbon ... do....	17.55	22.66	18.61
Ash ... do....	13.49	14.83	13.02
Sulphur ... do....	.97	1.58	1.08
Ultimate:			
Hydrogen ... do....	5.42	....	....
Carbon ... do....	53.37	....	....
Nitrogen ... do....	.61	....	....
Oxygen ... do....	16.72	....	....
Heat value ... B. t. u..	6,080	7,546	6,764

Proximate analyses of briquets.

	Test 308.	Test 309.	Test 310.	Test 311.	Test 313.	Test 314.	Test 315.	Test 329.
Laboratory No	7774	7757	7773	7775	7846	7861	7864	8018
Proximate:								
Moisture, per cent	9.07	6.66	7.85	7.34	9.17	12.66	10.40	9.82
Volatile matter, per cent	46.53	43.99	47.53	49.04	46.28	44.95	46.60	46.48
Fixed carbon, per cent	25.01	32.80	27.01	25.97	26.75	24.59	25.31	24.54
Ash....per cent..	19.39	16.55	17.61	17.65	17.80	17.80	17.69	19.16
Sulphur, p. cent..	1.83	1.70	1.56	1.51	1.48	1.24	1.47	1.77

Extraction analyses.

Briquets.	Test 308.	Test 309.	Test 310.	Test 311.	Test 313.	Test 314.	Test 315.	Test 329.
Laboratory No	7774	7757	7773	7775	7846	7861	7864	8018
Extracted by CS_2 (moisture free), per cent	7.02	7.01	7.60	7.76	7.98	8.35	7.97	....
Heat value..B. t. u..	9,227	10,138	9,704	9,734	9,360	8,942	9,131	9,187

TESTS ON THE LADLEY PRESS.

Briquetting tests of this lignite were conducted with the Ladley press. This press is described on page 36, and shown in Plate XV. The lignite was dried in the Schulz drier at the Pittsburgh plant until it contained 6.79 per cent moisture and then shipped to Indianapolis.

METHOD OF HEATING LIGNITE.

In tests 1, 4, 5, 6, 7, 8, and 9 each pailful of the material was heated by dry steam from the nozzle of a hose, the steam being taken from the dome of the boiler. The steam escaping from the nozzle was slightly superheated, and although the loss of heat from radiation was relatively large the lignite could be heated to a temperature of 208° F. The length of the heating was from one to two and a half minutes; the temperatures obtained were from 194° to 208° F. In tests 2, 3, and 10 the material was heated over a forge fire before pressing.

The molds for these tests were heated by placing a red-hot iron in a mold for some time. In some of the tests a gasoline torch, which gave a more even heat, was used. The dried and heated material was packed in the mold with a round bar and a sledge hammer, and the mold was again filled and tamped. Then the machine was started and the briquet was formed and ejected.

The briquets were 2½ inches in diameter and 3 inches long and weighed 10 to 10½ ounces.

The analyses of the briquet material before and after drying and of the briquets made from material heated by the two methods described are given in the following table:

Analyses of lignite and briquets.

	Material.		Briquets.	
	Before drying.	After drying.	Material heated by live steam.	Material heated by forge fire.
Moisture........per cent..	39.46	6.79	13.37	4.47
Volatile combustion........do....	29.50	48.72	44.36	47.43
Fixed carbon........do....	17.55	23.49	23.48	26.23
Ash........do....	13.49	21.00	18.79	21.87
Sulphur........do....	.97	1.86	1.54	1.82
Heat value........B. t. u..	6,080	9,126	8,662	9,538

The principal details of the tests are summarized as follows:

Details of tests 1 to 10 on the Ladley press.

Test No.	Heating of material.				Remarks.
	Method used.	Time of heating.	Temperature of material before pressing.	Quality of briquets obtained.	
		Minutes.	°*F.*		
1	Steam jet.....	(*a*)	(*b*)	Poor; too soft and dusty.	Mold too cold.
2	Forge fire.....	(*a*)	(*b*)	Poor; too dry...........	
3	.....do........	(*a*)	199	Fair........	Water added before heating, to replace evaporation.
4	Steam jet.....	(*a*)	199	Good........	Improvement made.
5	.....do........	(*a*)	(*b*)	Fair........	Mold too cold.
6	.....do........	1½	208	Good........	Satisfactory briquet.
[c]7	.....do........	2	205	Excellent........	Do.
8	.....do........	2½	194	.....do........	Do.
9	.....do........	1	176	Good........	Do.
10	Forge fire.....	(*a*)	212–230	Excellent........	Do.

[a] Not noted. [b] Not taken. [c] A test, 7A, was made under same conditions as test 7 on the following day.

The briquets made in tests 7 and 10 were smooth and hard and their edges sharp and firm. The briquets from test 7 had fewer surface cracks than those from test 10, although both lots were smooth enough. With steam in the steam jackets the molds would be hotter and the results might be even better.

The condensation of the steam used for heating the material in test 7 increased the moisture content of the material and of the resulting briquets. For this reason the briquets from that test had a lower heating value than those from test 10, in which the material was heated over a forge fire.

The tests demonstrated that without added binding material at least one American lignite could be made into good briquets by an American press.

STOVE AND GRATE COMBUSTION TESTS OF BRIQUETS.

Combustion tests of briquets of this California lignite were made at Pittsburgh, Pa., in a range and in an open heating grate to determine whether they fell to pieces while burning, the length of flame, and the quantity of smoke; also to determine the completeness of combustion as shown by the percentage of combustible matter in the refuse.

TESTS IN A KITCHEN RANGE.

The kitchen range had Dockash grates with openings one-half inch wide and could burn hard or soft coal. In the first trial the attempt was made to burn the briquets under the conditions present with the Pittsburgh coal regularly used. Some of the coal was mixed with the briquets, however, and the fire box was filled so high that proper combustion was impossible. For the next trial most of the coal was raked from the fire box and a fire gradually built with briquets alone. The results were excellent.

Briquets were added at half-hour intervals. The fire did not require much stirring, but it was raised slightly with a slice bar when it packed too much at the bottom. This did not cause excessive loss of unburned material through the grate, as was shown by the results of the test.

In five hours 32 briquets, or 32 pounds of fuel, was burned. The refuse weighed 8 pounds and was therefore 25 per cent of the fuel as fired. An analysis of the briquets showed the ash content to be 19.16 per cent.

Analysis of the refuse or "ashes" gave the following results:

	Per cent.
Moisture	2.52
Combustible matter	33.05
Ash (actual)	64.43

Only one-third of the refuse was combustible matter, and, as the refuse was 25 per cent of the fuel fired, the loss of combustible through the grates was 33.05×25=8.3 per cent of the coal, or 11.5 per cent of the combustible fired. The loss of 8.3 per cent is low for a kitchen stove, which at best does not burn fuel with high efficiency, and compares favorably with the percentage of loss for good bituminous coal burned in such a stove.

The proximate analyses of the briquets and of the refuse from the kitchen-stove and the heating-grate tests compare as follows:

Proximate analyses of briquets and of refuse from kitchen-stove and heating-grate tests.

Material.	Briquets.	Refuse from—	
		Kitchen-stove test.	Heating-grate test.
Moisture . . . per cent . .	9.82	2.52	0.77
Volatile matter . . . do . . .	46.48	. . . . . .	. . . . . .
Fixed carbon . . . do . . .	24.54	. . . . . .	. . . . . .
Ash . . . do . . .	19.16	64.43	72.60
Sulphur . . . do . . .	1.77	. . . . . .	. . . . . .
Heat value . . . B. t. u . .	9,187	. . . . . .	. . . . . .
Combustible matter . . . per cent . .	71.02	33.05	26.63

TESTS IN A HEATING GRATE.

Through the courtesy of the quartermaster's office, the author obtained the use of a heating grate in one of the vacant buildings on the arsenal grounds at Pittsburgh, Pa., for testing the combustion of the briquets in a heating grate. The grate was 24 inches wide, 9 inches deep at the center, and slightly less at the sides. The grate bars were of cast iron. The bottom bars ran from the back to the front and were spaced 1 inch apart. A fire was started in the grate with paper and a little wood, upon which was placed 25 pounds of briquets. A thermometer was hung on the outside of the building and another on the wall of the room about 4 feet in front and to one side of the fire and about 3 feet above the level of the grate. The temperatures taken were not expected to furnish data of interest. The main object of the tests was to note the combustion of the briquets and whether the economic results obtained were better than from tests under steam boilers.

Observations on grate test.

Time.	Temperature.		Weight of fuel as fired.
	Outside.	Inside.	
	°F.	*°F.*	*Pounds.*
9.30 a. m . . .	37	51	25
9.45 a. m . . .	37	55	20
10.30 a. m . . .	36	67	20
12 noon . . .	34	[a] 65	35
1.30 p. m . . .	31	64	0
4 p. m . . .	30	60	0
5 p. m . . .	29	55	0

[a] Drop of temperature caused by opening an outside door.

No fuel was added to the fire after 12 noon. At 5 p. m., after burning five hours without attention, the fire was practically burned out. The table shows that in 7½ hours 100 pounds of briquets was fired, giving 24 pounds, or 24 per cent, of refuse. After the briquets were well ignited they burned freely. They burned with a bright-yellow flame, much cleaner than the smoky flame from some bituminous coals, and the chimney showed only a slight yellowish smoke even directly after firing fresh fuel. The fire was unpleasantly hot to the face at a distance of 8 feet. No unpleasant odor could be detected in the room, though the gases from burning lignite have a characteristic odor and irritate the eyes and nose.

The combustible in the refuse was only 26.63 per cent, and as there was 24 per cent of refuse, the loss of fuel through the grate bars was approximately 6 per cent of the total fuel fired. This loss is no greater than from a coking coal burned under the same conditions. The loss through the grate of the kitchen range was approximately 8 per cent, or 2 per cent more than through the fireplace grate. The latter had wider spaces between the grate bars, but the fire in it did not need raking, whereas some raking of the kitchen-range grate was necessary.

The loss in both grates, however, was less than anticipated. The lignite used was noncoking, and one would naturally expect from it a larger loss of unburned material through the grate than from a coking coal.

CONCLUSIONS.

From the observed results of these combustion tests the following conclusions may be drawn:

The briquets ignite readily, make a hot fire, and burn freely until consumed.

Little shaking or poking of the fire is needed to obtain maximum efficiency from the fuel.

The loss of unburned fuel through the grates, 6 to 8 per cent, is not excessive and could be reduced by using step grates or grates with narrow spaces between the bars.

A grate measuring 8 by 24 inches is big enough for heating a large room with these briquets.

Under the test conditions little smoke was made; this smoke was light yellow, and would not be offensive in residential districts.

The briquets should prove a satisfactory domestic fuel, and, if they can be produced cheaply enough, should compete with other fuels for steam production.

COLORADO NO. 1.

A sample of run-of-mine subbituminous coal from Lafayette, Boulder County, on the Colorado & Southern Railroad of the Burlington system, was designated Colorado No. 1, and a part of the sample was subjected to briquetting tests.

It was first used undried with 10 per cent of pitch D. As these briquets were received from the English machine they were hard to handle, especially when there was an excess of steam. The pitch did not seem to adhere to the grains of lignite. On cooling, however, they became hard, black, and lustrous, but were too brittle. The adhesion of the pitch to the grains of lignite was not strong. The briquets seemed to be too pitchy, and if the adhesion between the pitch and the lignite were greater, 8 per cent of pitch D would undoubtedly be sufficient to give the desired results. Although there was no steaming test made with the briquets, they were burned under a boiler, and proved satisfactory. They weighed 5.98 pounds each. Some of the mixture was tested on the American machine, but the eggettes were much inferior to the briquets.

Chemical analysis.

	Car sample.		Car sample.
Laboratory No.	1523	Ultimate:	
Proximate:		Hydrogen .... per cent	4.91
Air-drying loss .... per cent	6.00	Carbon .... do	70.66
Moisture .... do	18.68	Nitrogen .... do	1.41
Volatile matter .... do	34.88	Oxygen .... do	14.97
Fixed carbon .... do	40.45	Heat value .... B. t. u.	10,143
Ash .... do	5.99		
Sulphur .... do	.55		

ILLINOIS NO. 1.

A sample of bituminous coal (over 1-inch screen) from O'Fallon, St. Clair County, on the Belt Terminal Railroad of East St. Louis, was designated Illinois No. 1, and a part of the sample was subjected to briquetting tests at the St. Louis plant.

Briquets from this coal were first made with the hard pitch X as a binder. One and a quarter tons of this coal was briquetted on the English machine with 16 per cent of pitch X, but on account of the softness and roughness of the coal the briquets were brown and soft, resembling pressed damp loam. They were, however, compact.

Chemical analysis.

	Car sample.
Laboratory No.	1261
Proximate:	
Air-drying loss, per cent	3.70
Moisture, do	9.75
Volatile matter, do	37.48
Fixed carbon, do	39.57
Ash, do	13.20
Sulphur, do	4.10
Ultimate:	
Hydrogen, per cent	4.69
Carbon, do	66.17
Nitrogen, do	1.14
Oxygen, do	8.83
Heat value, B. t. u.	11,025

ILLINOIS NO. 4.

A sample of bituminous coal (over 2-inch screen) from about 1 mile west of Troy, Madison County, on the St. Louis, Troy & Eastern Railroad, was designated Illinois No. 4 and a part of the sample was subjected to briquetting tests at the St. Louis plant.

Two tons of this coal was briquetted with 6 per cent of pitch D. The coal was not finely ground, only one side of the disintegrator being used. There was a great deal of water in the steam, and the briquets were full of the usual perpendicular cracks. A high pressure was used, and some of the briquets were larger than the normal size, a result that was due to the compression of the spring of the machine. The average weight of these briquets was 6.95 pounds The briquets varied considerably in texture, some being hard and firm and others crumbly. They would not stand much rough handling. Their specific gravity was 1.16, and their crushing strength was only 5,100 pounds, or 181 pounds to the square inch. Some of the mixture was tried also on the American machine, and the eggettes were better than the briquets made on the English machine. They were lustrous and deep black.

One ton of this coal was briquetted with 8 per cent of pitch D, only one side of the disintegrator and the maximum pressure being used. Excellent briquets were obtained with this combination, but they were gray in color. They weighed 6.34 pounds each, and had a specific gravity of 1.11. The specific gravity of the coal is 1.34. The crushing strength of these briquets was 9,327 pounds or 325 pounds per square inch, as compared with 181 pounds to the square inch when 6 per cent of pitch D was used as a binder. The eggettes made of this mixture on the American machine were not so strong as the briquets.

In the next test with Illinois No. 4 coal, 2 tons of the coal was briquetted with 8 per cent of pitch E. The average weight of the briquets was only 6.15 pounds. Only one side of the disintegrator was used, and as the coal was hard the briquets were coarse and contained many noticeably large pieces of coal. The eggettes made from this mixture, on the other hand, were much better in quality and rather lustrous, but of a decidedly brownish color. The specific gravity of the briquets was 1.13 and their crushing strength 7,265 pounds, or 263 pounds to the square inch. To test the effect of finer grinding, another ton of this coal was briquetted with 8 per cent of pitch E, both sides of the disintegrator being used. In these briquets there were a few grains of coal as big as a kernel of corn; but for the most part the material was too fine for the percentage of pitch, and the resultant briquets were crumbly, their crushing strength being only 209 pounds to the square inch, although they were well-pressed and lustrous and had a specific gravity of 1.03. There was little difference in the properties of the eggettes and the briquets made of this mixture. Another ton of this coal briquetted with 9 per cent of pitch E, both sides of the disintegrator and a maximum pressure being used, gave briquets of much better quality that would, however, have been improved by the addition of another one-half per cent of pitch. These briquets weighed 6.43 pounds each; their specific gravity was 1.08, and their crushing strength 9,125 pounds, or 352 pounds to the square inch. The eggettes made from this mixture were as good as the briquets and were more lustrous.

Another test was made with Illinois No. 4 coal and pitch H, which is a by-product from the manufacture of gas from heavy petroleum. Although this pitch would be rather soft to work on the English machine on a hot day, it is readily cracked and mixed on a cold day. One ton of the coal was briquetted with 8 per cent of pitch H, and the briquets were strong, clean, and satisfactory, being much better than any of the other briquets made with this coal. They were readily handled when taken from the machine, and when cold were hard and tough and capable of standing a great deal of rough handling. Their average weight was 6.81 pounds each and their specific gravity was 1.11. Their crushing strength was 12,810 pounds, or 446 pounds to the square inch, the briquets being hardest of all those made from Illinois coal.

The last test made with this coal was with a soft asphalt received from the Gulf Refining Co. In freezing weather this asphalt became hard enough to crack and could then be used on the English machine. On account of the cold weather there was considerable water in the steam, which produced cracks. Because of this fact and the low melting point and thinness of the asphalt while hot, the briquets were difficult to handle as they came from the machine. They were, however, well pressed and on cooling became tough and would stand much handling. The weight of these briquets was 6.77 pounds each. A better result can probably be obtained by using a small percentage of rosin with the asphalt.

Chemical analysis.

	Car sample.		Car sample.
Laboratory No	1417	Ultimate:	
Proximate:		Hydrogen ... per cent	4.59
Air-drying loss ... per cent	1.70	Carbon ... do	69.74
Moisture ... do	12.91	Nitrogen ... do	1.32
Volatile matter ... do	31.90	Oxygen ... do	9.46
Fixed carbon ... do	43.55	Heat value ... B. t. u	10,804
Ash ... do	11.64		
Sulphur ... do	1.32		

ILLINOIS NO. 7E.

Screened nut coal from a mine near Collinsville was designated Illinois No. 7E. Steaming test 516 was made of the unbriquetted fuel, but no steaming test was made of the briquets.

Renfrow briquets made with 8 per cent of binder were satisfactory, were easily transported from the machine without breaking, and became very hard when cold; their fractured surface was rough and their edges easily crumbled, owing to the excessive amount of clay present; the outer surfaces were smooth, with dull color.

Briquetting test.

	Test 244.		Test 244.
Size as used:		Drop test (1-inch screen):	
Over ¼ inch ... per cent	1.5	Held ... per cent	63.5
1/10 inch to ¼ inch ... do	6.6	Passed ... do	36.5
1/20 inch to 1/10 inch ... do	14.2	Tumbler test (1-inch screen):	
1/40 inch to 1/20 inch ... do	22.0	Held ... do	87.5
Through 1/40 inch ... do	55.7	Passed ... do	12.5
Details of manufacture:		Fines through 10-mesh sieve, per cent	97.2
Machine used	Renfrow No. 1	Absorption test:	
Briquetting temperature °F	167	Time immersed ... days	10
Binder—		Water absorbed ... per cent	7.4
Kind	W. G. P.	Average for first 4 days ... do	1.9
Laboratory No	4806	Specific gravity (apparent)	1.257
Amount ... per cent	8		
Weight of—			
Fuel briquetted ... pounds	12,000		
Briquets, average ... do	0.472		

Chemical analyses of coal and briquets.

	Car sample.	Test 244.
Laboratory No	4760	4928
Proximate:		
Moisture ... per cent	14.47	6.06
Volatile matter ... do	28.14	30.09
Fixed carbon ... do	35.16	40.34
Ash ... do	22.23	23.51
Sulphur ... do	3.73	5.09
Ultimate:		
Hydrogen ... do	3.84	3.57
Carbon ... do	56.08	59.48
Nitrogen ... do	.91	.83
Oxygen ... do	8.82	5.67

Extraction analyses.

	Pitch.	Fuel.	Briquets.
		Ill. No. 7E.	Test 244.
Laboratory No.	4806	4760	4928
Air-drying loss . . . per cent		10.60	1.70
Extracted by CS_2 (as received) . . . do	96.90	.42	8.09
Pitch in briquet by analysis . . . do			7.96
Heat value . . . B. t. u.	16,864	8,797	10,021

ILLINOIS NO. 9C.

Bituminous slack coal from a mine near Staunton was designated Illinois No. 9C. Steaming tests 492 and 497 were made on this fuel in the briquetted form.

Briquets made on the English machine with 6 and 7 per cent of binder were satisfactory, having hard surfaces but rough fracture without crumbling.

Renfrow briquets made with 8 and 9 per cent of binder were inferior to those made on the English machine with 6 and 7 per cent of binder and were soft, although they stood handling from the machine; their fractured surfaces were crumbly, but the briquets were tough in texture. This coal requires high pressure to make good briquets.

From all these tests the briquets when cold and dried had excellent strength, as will be seen by noticing the results of the drop and the tumbler tests.

Briquetting tests.

	Test 189.	Test 190.	Test 223.	Test 234.
Size as shipped	Slack.	Slack.	Slack.	Slack.
Size as used:				
Over ¼ inch . . . per cent	0.4	0.4	0.4	0.4
1/10 inch to ¼ inch . . . do	3.9	3.9	3.9	3.9
1/20 inch to 1/10 inch . . . do	14.4	14.4	14.4	14.4
1/40 inch to 1/20 inch . . . do	25.1	25.1	25.1	25.1
Through 1/40 inch . . . do	56.2	56.2	56.2	56.2
Details of manufacture:				
Machine used	English.	English.	Renfrow No. 1	Renfrow No. 1
Briquetting temperature . . . °F	167	167	149	149
Binder—				
Kind	W. G. P.	W. G. P.	W. G. P.	W. G. P.
Laboratory No.	4543	4543	4806	4806
Amount . . . per cent	6	7	8	9
Weight—				
Fuel briquetted . . . pounds	12,000	12,000	18,000	5,000
Briquets, average . . . do	3.85	3.73	0.448	0.426
Drop test (1-inch screen):				
Held . . . per cent	62.0	57.0	54.5	64.5
Passed . . . do	38.0	43.0	45.5	35.5
Tumbler test (1-inch screen):				
Held . . . do	77.2	76.2	87.5	88.5
Passed . . . do	22.8	23.8	12.5	11.5
Fines through 10-mesh sieve . . . do	80.3	81.4	95.5	84.6
Weather test:				
Time exposed . . . days	6	6		
Condition	B	B		
Absorption test:				
Time immersed . . . days	19	19	13	13
Water absorbed . . . per cent	9.4	12.0	10.2	9.1
Average for first 4 days . . . do	1.67	2.03	2.43	2.17
Specific gravity (apparent)	1.146	1.124	1.098	1.128

Chemical analyses of coal and briquets.

	Car sample.	Test 189.	Test 190.	Test 234.
Laboratory No.	4247	4406	4473	4874
Proximate:				
Moisture ... per cent..	15.25	14.62	17.43	5.43
Volatile matter ... do....	28.57	32.38	28.98	33.55
Fixed carbon ... do....	40.83	39.13	39.99	47.63
Ash ... do....	15.35	13.87	13.60	13.39
Sulphur ... do....	3.81	3.51	3.30	3.52
Ultimate:				
Hydrogen ... do....	4.17	4.33	4.31	4.44
Carbon ... do....	63.66	65.67	66.29	68.44
Nitrogen ... do....	.97	.88	.99	.94
Oxygen ... do....	8.59	8.77	7.94	8.30

Extraction analyses.

	Pitches.		Fuel.	Briquets.		
			Ill. No. 9.	Test 189.	Test 190.	Test 234.
Laboratory No.	4543	4806	4247	4406	4473	4874
Air-drying loss ... per cent..			13.30	12.30	15.10	3.10
Extracted by CS_2 (as received) ... do....	99.66	96.90	.63	6.30	6.18	9.41
Pitch in briquet by analysis ... do....				5.75	5.50	9.12
Heat value ... B. t. u..	16,969	16,864	9,790	10,276	9,943	11,713

ILLINOIS NO. 12B.

Bituminous coal from Bush, Williamson County, designated Illinois No. 12B, was No. 5 washed, and this sample was shipped uninspected and used washed in briquetting tests 166, 177, and 181.

Steaming test 463 was made of briquets from this sample.

English briquets made with 6.25 per cent of binder and Renfrow briquets made with 7 per cent of binder were of excellent quality. Briquets were easily handled when warm, although some difficulty was experienced in piling Renfrow briquets, as they stuck together on account of the low melting point of the pitch used. The surfaces of all briquets were hard and smooth, with rough, clean fracture and sharp edges.

Eight per cent of binder is more than is necessary to make satisfactory briquets from this fuel.

Briquetting tests.

	Test 166.	Test 177.	Test 181.
Size as shipped	No. 5.	No. 5.	No. 5.
Size used:			
Over $\frac{1}{4}$ inch ... per cent	0.2	0.2	0.2
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch ... do	3.4	3.4	3.4
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch ... do	15.2	15.2	15.2
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch ... do	24.4	24.4	24.4
Through $\frac{1}{40}$ inch ... do	56.8	56.8	56.8
Details of manufacture:			
Machine used	Renfrow No. 1.	English.	Renfrow No. 1.
Briquetting temperature ... °F	131	185	131
Binder—			
Kind	W. G. P.	W. G. P.	W. G. P.
Laboratory No	4120	4543	4543
Amount ... per cent	8	6.25	7
Weight—			
Fuel briquetted ... pounds	100,000	51,000	53,000
Briquets, average ... do	0.463	3.66	0.432
Drop test (1-inch screen):			
Held ... per cent	66.5	85.1	65.5
Passed ... do	33.5	14.9	34.5
Tumbler test (1-inch screen):			
Held ... do	83.5	84.5	84.0
Passed ... do	16.5	15.5	16.0
Fines through 10-mesh sieve ... do	96.5	78.3	96.0
Weather test:			
Time exposed ... days	63	12	19
Condition	B	A	B
Absorption test:			
Time immersed ... days	19	19	19
Water absorbed ... per cent	13.3	8.5	15.0
Average for first 4 days ... do	2.15	1.00	2.13
Specific gravity (apparent)	1.074	1.101	1.041

Chemical analyses of coal and briquets.

	Car sample.	Test 166.	Test 177.	Test 181.
Laboratory No	4201	4228	....	....
Proximate:				
Moisture ... per cent	15.87	6.99	5.57	5.78
Volatile matter ... do	28.19	32.36	32.38	32.62
Fixed carbon ... do	46.42	50.24	50.96	49.80
Ash ... do	9.52	10.41	11.09	11.80
Sulphur ... do	2.34	2.41	2.41	2.58
Ultimate:				
Hydrogen ... do	4.56	4.49	4.20	4.59
Carbon ... do	70.91	72.03	70.09	71.48
Nitrogen ... do	1.26	1.09	1.11	1.09
Oxygen ... do	9.17	8.61	10.28	7.57

Extraction analyses.

	Pitches.		Fuel.	Briquets.		
			Ill. No. 12B.	Test 166.	Test 177.	Test 181.
Laboratory No	4120	4543	4201	4228	....	....
Air-drying loss ... per cent	....	....	13.30	4.10	....	....
Extracted by CS_2 (as received) ... do	97.70	99.66	.02	6.27	6.35	6.05
Pitch in briquet by analysis ... do	....	....	....	6.40	6.35	6.05
Heat value ... B. t. u	17,060	16,969	10,784	11,961	12,155	12,076

ILLINOIS NO. 20.

Bituminous coal from Staunton, Macoupin County, on the Litchfield & Madison Railroad, was designated Illinois No. 20. The sample consisted of screenings, and was shipped by the operator primarily for washing tests, but some of it was used in briquetting tests 103 and 104 in a mixture with Kentucky No. 2B (coke breeze).

Briquets made from coke breeze with 20 per cent, 33⅓ per cent, and 47 per cent of coal and 6 per cent of pitch were easily broken in handling. The coke breeze was washed, one-half being used wet and one-half put through a drier. Briquets made with dried fuel could be handled better when hot, but there was no difference between the two types when cold. Washed breeze was too high in ash for satisfactory fuel. These briquets were used in a preliminary test in switching locomotives. Briquets with 20 per cent of coal burned too slowly for switching service. Briquets with 33⅓ per cent of coal were satisfactory for switching, but burned too slowly for freight or passenger service. Briquets with 47 per cent of coal were satisfactory for all services. No analyses of the briquets were made.

Size as shipped, breeze through 1-inch coke fork and coal screenings; machine used, English; briquetting temperature, 179.6° F.; kind of binder, coal-tar pitch; proportion of binder, 6 per cent; laboratory number of binder, 2729; weight of fuel briquetted, 2,000 pounds.

Chemical analysis.

	Car sample.		Car sample.
Laboratory No	2731	Ultimate:	
Proximate:		Hydrogen........per cent..	4.43
Air-drying loss........per cent..	12.40	Carbon........do....	64.71
Moisture........do....	14.68	Nitrogen........do....	1.17
Volatile matter........do....	31.32	Oxygen........do....	9.11
Fixed carbon........do....	40.32	Heat value........B. t. u..	10,053
Ash........do....	13.68		
Sulphur........do....	3.88		

ILLINOIS NO. 21.

Bituminous coal from Troy, Madison County, on the St. Louis, Troy & Eastern Railroad, was designated Illinois No. 21. Sample consisted of lump coal over a 2¼-inch screen. A part of this sample, 14,000 pounds, was used in briquetting test 113. Steaming test 318 was made of the briquets from this test.

Machine used, English; briquetting temperature, 179.6° F.; kind of binder, coal-tar pitch; laboratory number of binder, 2933; amount of binder used, 5 and 6 per cent; weight of fuel briquetted, 14,000 pounds.

Briquets made with 5 per cent of binder were hard and firm, and stood rough handling. Weathering test: Days exposed, 75; condition of briquets made with 5 per cent binder, B.

Chemical analyses of coal and briquets.

	Car sample.	Test 113.
Laboratory No.	2852	....
Proximate:		
Air-drying loss .... per cent..	10.40	....
Moisture .... do....	15.54	17.31
Volatile matter .... do....	31.26	30.40
Fixed carbon .... do....	42.27	42.28
Ash .... do....	10.93	10.01
Sulphur .... do....	1.38	1.28
Ultimate:		
Hydrogen .... do....	4.57	4.41
Carbon .... do....	68.69	70.01
Nitrogen .... do....	1.29	1.32
Oxygen .... do....	10.88	10.61
Heat value [a] .... B. t. u..	10,507	10,309

[a] Heat value of binder (Lab. No. 2933), 15,937 B. t. u.

ILLINOIS NO. 23B.

Bituminous slack coal, through 2-inch perforated screen, from Donkville, Madison County, on the St. Louis, Troy & Eastern Railroad, was designated Illinois No. 23B. Briquetting test 116 was made of this sample of coal. Steaming tests 321 and 322 were made of the briquetted fuel.

Briquets made with 5 and 6 per cent broke in handling. Those made with 6.5 per cent were satisfactory. In the weathering test all briquets were exposed 70 days; the condition of the briquets made with 5 per cent of binder was D; of those made with 6 per cent, C; and of those made with 6.5 per cent, B.

Briquetting test.

	Test 116.		Test 116.
Size as shipped	([a])	Details of manufacture—Continued.	
Details of manufacture:		Binder—Continued.	
Machine used	English.	Laboratory No	2933
Briquetting temperature, °F	179.6	Amount .... per cent..	5, 6, 6.5
Binder—		Weight of fuel briquetted .... pounds..	12,000
Kind	C. T. P.		

[a] Through 2½-inch screen.

Chemical analyses of coal and briquets.

	Car sample.	Test 116.[a]	Binder.
Laboratory No	2803	....	2933
Proximate:			
Air-drying loss .... per cent..	13.20	....	....
Moisture .... do....	15.68	13.54	....
Volatile matter .... do....	31.28	36.33	....
Fixed carbon .... do....	37.45	41.67	....
Ash .... do....	15.59	8.41	....
Sulphur .... do....	3.98	3.21	....
Ultimate:			
Hydrogen .... do....	4.36	4.86	....
Carbon .... do....	62.72	69.30	....
Nitrogen .... do....	1.07	1.14	....
Oxygen .... do....	8.64	11.26	....
Extract by CS_2 (as received) .... do....	....	....	64.20
Heat value .... B. t. u..	9,655	12,996	15,937

[a] Composite sample of briquets.

ILLINOIS NO. 28A.

Bituminous coal from bed No. 7 at Herrin, Williamson County, was designated Illinois No. 28A. This sample consisted of No. 5 washed coal, and a portion of it was used in briquetting tests 140, 141, 142, 143, 162, and 163 at St. Louis. Steaming test 459 was made with the briquets from tests 162 and 163 (equal weights of each).

There was no appreciable difference in briquets with 6, 7, and 8 per cent of binder made on the English machine and 8 per cent made on the Renfrow No. 1 machine. Renfrow briquets made with less than 8 per cent of binder were not satisfactory. The satisfactory briquets had hard, smooth outer surfaces, broke with clean, rough fracture without crumbling, and their edges were hard and sharp. Renfrow briquets could be handled warm and could be piled without crushing.

Briquetting tests.

	Test No.					
	140.	141.	142.	143.	162.	163.
Size as shipped	(a)	(a)	(a)	(a)	(a)	(a)
Size as used:						
Over $\frac{1}{4}$ inch.....per cent..	0.0	0.0	0.0	0.0	0.0	0.0
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch....do....	3.0	3.0	3.0	3.0	3.0	3.0
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch...do....	13.0	13.0	13.0	13.0	13.0	13.0
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch...do....	20.2	20.2	20.2	20.2	20.2	20.2
Through $\frac{1}{40}$ inch....do....	63.8	63.8	63.8	63.8	63.8	63.8
Details of manufacture:						
Machine used	English.	English.	English.	Renfrow No. 1	Renfrow No. 1	English.
Briquetting temperature, °F	185	185	185	131	131	185
Binder—						
Kind	W.G.P.	W.G.P.	W.G.P.	W.G.P.	W.G.P.	W.G.P.
Laboratory No	3410	3410	3410	3410	3885	3885
Amount....per cent..	6	7	8	8	7	7
Weight of—						
Fuel briquetted..lbs..	16,000	16,000	16,000	134,000	40,000	8,000
Briquets, average, pounds	3.44	3.54	3.45	0.502	0.463	3.62
Drop test (1-inch screen):						
Held............per cent..	....	....	....	....	61.5	....
Passed..............do....	....	....	....	....	38.5	....
Tumbler test (1-inch screen):						
Held................do....	....	....	....	....	73.5	....
Passed..............do....	....	....	....	....	26.5	....
Fines through 10-mesh sieve..........per cent..	....	....	....	....	94.5	....
Weather test:						
Time exposed......days..	182	182	182	173	127	173
Condition	A	B	A	B	B	B
Absorption test:						
Time immersed.....days..	....	....	....	....	19	....
Water absorbed.per cent..	....	....	....	....	13.6	....
Average for first 4 days.do.	....	....	....	....	1.84	....
Specific gravity (apparent)....	....	....	....	....	1.041	....

(a) Washed screenings.

Chemical analyses of coal and briquets.

	Car sample.	Test 140.	Test 142.	Test 143.	Tests 162 and 163.
Laboratory No.	3409	....	....	4066	....
Proximate:					
Moisture ..... per cent	14.67	5.81	5.75	5.78	7.32
Volatile matter ..... do	26.17	30.31	31.06	30.58	30.72
Fixed carbon ..... do	46.62	49.58	51.50	51.02	49.84
Ash ..... do	12.54	14.30	12.61	12.62	12.12
Sulphur ..... do	1.05	1.25	1.21	.95	1.29
Ultimate:					
Hydrogen ..... do	4.14	4.21	4.16	4.35	4.21
Carbon ..... do	70.65	69.69	71.92	71.89	71.88
Nitrogen ..... do	1.56	1.36	1.35	1.36	1.59
Oxygen ..... do	7.72	8.23	7.95	8.00	7.85

Extraction analyses.

	Pitches.		Fuel.	Briquets.			
			Ill. No. 28A.	Test 140.	Test 142.	Test 143.	Tests 162 and 163.
Laboratory No.	3410	3885	3409	....	....	4066	....
Air-drying loss ..... per cent	....	....	9.30	....	....	....	....
Extracted by CS_2 (as received), per cent	79.98	95.20	0.21	....	....	9.15	....
Pitch in briquet by analysis, per cent	....	....	....	....	....	11.21	....
Heat value ..... B. t. u.	16,478	16,870	10,611	11,561	11,927	12,026	11,637

ILLINOIS NO. 28B.

Unwashed bituminous screenings from bed No. 7 at Herrin, Williamson County, was designated Illinois No. 28B, and a part of the sample was used in briquetting tests 144, 158, 159, 160, and 161. Steaming test 457 was made of the briquets from tests 159 and 161 (equal weights of each).

These briquets showed the same characteristics as those made from Illinois No. 28A coal, except that when cold their surfaces were tougher and less liable to break from abrasion than those of the briquets made of the washed fuel.

Briquetting tests.

	Test No.				
	144.	158.	159.	160.	161.
Size as shipped	(a)	(a)	(a)	(a)	(a)
Size as used:					
Over $\frac{1}{4}$ inch ... per cent	0.4	0.4	0.4	0.4	0.4
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch ... do	3.8	3.8	3.8	3.8	3.8
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch ... do	13.4	13.4	13.4	13.4	13.4
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch ... do	24.8	24.8	24.8	24.8	24.8
Through $\frac{1}{40}$ inch ... do	57.6	57.6	57.6	57.6	57.6
Details of manufacture:					
Machine used	Renfrow No. 1.	English.	English.	English.	Renfrow No. 1
Briquetting temperature ... °F	131	185	185	185	131
Binder—					
Kind	W. G. P.	C. T. P.	C. T. P.	C. T. P.	W. G. P.
Laboratory No	3486 3624	3692	3692	3692	3692 3885
Amount ... per cent	[b] 8	6	7	8	8
Weight of -					
Fuel briquetted ... pounds	123,000	20,000	28,000	20,000	30,000
Briquets, average ... do	0.524	3.50	3.51	3.63	0.481
Drop test (1-inch screen):					
Held ... per cent	49.0	77.9	72.3	80.6	41.0
Passed ... do	51.0	22.1	27.7	19.4	59.0
Tumbler test (1-inch screen):					
Held ... do	79.0	77.8	72.1	66.4	59.5
Passed ... do	21.0	22.2	27.9	33.6	40.5
Fines through 10-mesh sieve ... do	85.0	80.0	87.7	78.3	89.5
Weather test:					
Time exposed ... days	141	143	137	137	112
Condition	C	B	B	B	C
Absorption test:					
Time immersed ... days	19	19	19	19	19
Water absorbed ... per cent	15.5	14.3	12.6	13.9	16.0
Average for first 4 days ... do	1.98	1.40	1.30	1.40	2.14
Specific gravity (apparent)	1.075	1.092	1.112	1.075	1.038

[a] Unwashed screenings.

[b] Equal weights of the two binders were used.

Chemical analyses of coal and briquets.

	Car sample.	Test 144.	Tests 158, 159, and 160.	Test 161.
Laboratory No	3423	4144	4150	4121
Proximate:				
Moisture ... per cent	9.87	6.38	5.45	5.81
Volatile matter ... do	29.21	31.07	31.65	30.86
Fixed carbon ... do	48.47	51.19	51.74	52.41
Ash ... do	12.45	11.36	11.16	10.92
Sulphur ... do	2.19	1.55	2.04	2.03
Ultimate:				
Hydrogen ... do	4.08	4.22	4.19	4.60
Carbon ... do	70.23	71.82	71.62	71.92
Nitrogen ... do	1.45	1.39	1.43	1.37
Oxygen ... do	8.00	8.78	8.80	8.36

Extraction analyses.

	Pitches.				Fuel.	Briquets.		
					Ill. No. 28B.	Test 144.	Tests 158, 159, and 160.	Test 161.
Laboratory No	3486	3624	3692	3885	3423	4144	4150	4121
Air-drying loss ... per cent	...	...	...	...	6.20	...	...	2.90
Extract by CS_2 (as received) per cent	87.57	99.60	69.71	95.20	.23	7.54	5.12	5.79
Pitch in briquet by analysis, per cent	...	...	...	...	...	8.57	7.02	6.77
Heat value ... B. t. u.	16,407	16,193	16,103	16,870	11,329	12,094	12,161	12,092

ILLINOIS NOS. 29A AND 29B.

Bituminous screenings through a 2-inch shaking screen from bed No. 5 at Livingston, Madison County, were designated Illinois No. 29A, and briquetting tests 170 and 171 were made of a washed part of the sample. Steaming test 465 was made of the briquetted fuel.

Run-of-mine coal from the same location was designated Illinois No. 29B, and briquetting test 175 was made of a part of the sample. Steaming test 466 was made of the briquetted fuel.

Tests 170 and 171, made of washed screenings with 7 per cent of binder on the English and Renfrow No. 1 machines, respectively, furnished satisfactory briquets in each case. The briquets were very hard and tough and broke with rough fracture and hard edges. Renfrow briquets were well molded and stood handling when warm.

Briquets from test 175 made of the raw run-of-mine coal were identical with those made of the washed coal, except that the fracture was rougher and harder, as the fuel did not crush so fine in grinding.

Briquetting tests.

	Ill. No. 29A.		Ill. No. 29B.
	Test 170.	Test 171.	Test 175.
Size as shipped	(a)	(a)	r. o. m.
Size as used:			
Over $\frac{1}{4}$ inch ... per cent	3.6	3.6	3.2
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch ... do	8.6	8.6	9.8
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch ... do	16.2	16.2	16.4
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch ... do	20.8	20.8	25.8
Through $\frac{1}{40}$ inch ... do	50.8	50.8	44.8
Details of manufacture:			
Machine used	English.	Renfrow No. 1.	Renfrow No. 1.
Briquetting temperature ... °F	203	131	131
Binder—			
Kind	W. G. P. C. T. P.	W. G. P.	W. G. P.
Laboratory No	4319 4543	4543	4543
Amount ... per cent	[b] 7	7	7
Weight of fuel briquetted ... pounds	6,000	24,000	15,000
Average weight of briquet ... do	3.84	0.437	0.465
Drop test (1-inch screen):			
Held ... per cent	74.4	47.0	50.5
Passed ... do	25.6	53.0	49.5
Tumbler test (1-inch screen):			
Held ... do	94.0	75.0	77.5
Passed ... do	6.0	25.0	22.5
Fines through 10-mesh sieve ... do	1.2	87.3	90.2
Weather test:			
Time exposed ... days	56	55	53
Condition	C	B	B
Absorption test:			
Time immersed ... days	19	19	19
Water absorbed ... per cent	17.0	21.5	18.8
Average for first 2 days ... do	5.15	5.05	...
Average for first 5 days ... do	...	...	2.42
Specific gravity (apparent)	1.053	0.969	1.052

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[a] Washed screenings.

[b] Equal weights of the two pitches were used and the calorific value was determined from the separate calorific values of the two pitches.

Chemical analyses of coal and briquets.

	Car sample, Ill. 29A.	Car sample, Ill. 29B.	Test 170.	Test 171.	Test 175.
Laboratory No	3963	3958	4233	4581	4245
Proximate:					
Moisture per cent	13.10	12.47	14.23	12.29	10.00
Volatile matter do	30.78	33.12	34.63	37.16	36.33
Fixed carbon do	40.12	41.85	43.96	43.99	43.01
Ash do	16.00	12.56	7.18	6.56	10.66
Sulphur do	4.17	4.37	2.84	3.56	3.24
Ultimate:					
Hydrogen do	4.37	4.55	4.78	4.91	4.82
Carbon do	62.44	65.31	72.39	72.23	69.45
Nitrogen do	1.02	1.14	1.08	1.07	1.26
Oxygen do	8.96	19.66	10.07	10.26	9.03

Extraction analyses.

	Pitches.		Fuel.		Briquets.		
			Ill. No. 29A.	Ill. No. 29B.	Test 170.	Test 171.	Test 175.
Laboratory No	4319	4543	3963	3958	4233	4581	4245
Air-drying loss per cent			8.60	7.30	11.80	10.40	7.80
Extract by CS_2 (as received) do	66.25	99.66	.76	.92	5.83	6.77	6.38
Pitch in briquet by analyses do					6.17	6.09	5.53
Heat value B. t. u.	16,139	16,969	9,983	10,667	11,254	11,671	11,486

ILLINOIS NO. 30.

Bituminous nut coal, through a 3-inch and over a 2-inch shaking screen, from bed No. 7 at Shiloh Station, St. Clair County, on the Southern Railway, was used in briquetting tests 225, 226, and 228. Steaming test 511 was made of the briquets.

Briquets from all three tests were satisfactory and had hard, rough exteriors, and broke with rough, uneven fractures, but had somewhat crumbly edges. All briquets had a bluish color and fracture, which showed an excess of pitch. The Renfrow briquets showed the results of insufficient pressure. No analyses were made of the briquets resulting from test 228.

Briquetting tests.

	Test 225.	Test 226.	Test 228.
Size as shipped	(a)	(a)	(a)
Size as used:			
Over 1/4 inch, per cent	2.0	2.0	2.0
1/10 inch to 1/4 inch, do	7.0	7.0	7.0
1/20 inch to 1/10 inch, do	17.4	17.4	17.4
1/40 inch to 1/20 inch, do	20.8	20.8	20.8
Through 1/40 inch, do	52.8	52.8	52.8
Details of manufacture:			
Machine used	English.	English.	Renfrow No. 1.
Briquetting temperature, °F	185	185	158
Binder—			
Kind	W. G. P.	W. G. P.	W. G. P.
Laboratory No.	4806	4806	4806
Amount, per cent	6	7	8.5
Weight of:			
Fuel briquetted, pounds	6,000	6,000	6.500
Briquets, average, do	3.50	3.45	0.463
Drop test (1-inch screen):			
Held, per cent	80.2	81.5	47.0
Passed, do	19.8	18.5	53.0
Tumbler test (1-inch screen):			
Held, do	75.9	79.0	82.5
Passed, do	24.1	21.0	17.5
Fines through 10-mesh sieve, do	82.6	85.0	95.0
Absorption test:			
Time immersed, days	13	13	23
Water absorbed, per cent	8.6	8.5	16.2
Average for first 4 days, do	1.35	1.98	2.10
Specific gravity (apparent)	1.087	1.080	1.060

[a] Nut, washed.

Chemical analyses of coal and briquets.

	Car sample.	Tests 225 and 226.
Laboratory No.	4364	4714
Proximate:		
Moisture, per cent	11.69	9.75
Volatile matter, do	35.70	39.25
Fixed carbon, do	39.42	42.69
Ash, do	13.19	8.31
Sulphur, do	4.38	3.21
Ultimate:		
Hydrogen, do	4.71	4.80
Carbon, do	64.72	71.70
Nitrogen, do	1.06	1.13
Oxygen, do	9.61	9.60

Extraction analyses.

	Pitch.	Fuel.	Briquets.
		Ill. No. 30B.	Tests 225 and 226.
Laboratory No.	4806	4364	4714
Air-drying loss, per cent	....	8.70	5.3
Extracted by CS_2 (as received), do	96.90	.61	6.18
Pitch in briquet by analysis, do	....	....	5.80
Heat value, B. t. u.	16,864	10,699	11,977

ILLINOIS NO. 31.

Bituminous screenings, over a $1\frac{1}{4}$-inch shaking screen, from bed No. 6, at Worden, St. Clair County, on the Wabash Railroad, were designated Illinois No. 31, and a part of this sample was used in briquetting tests 185, 186, 224, and 237. Steaming tests 489 and 491 were made of the briquets.

The briquets were porous, with soft surfaces, rough fracture, and easily crumbled edges. English briquets were handled from the machine without breaking. Renfrow briquets were not satisfactory, owing to low pressure. This coal, although dirty, should be a good briquetting coal.

Briquetting tests.

	Test 185.	Test 186.	Test 224.	Test 237.
Size as shipped	(*a*)	(*a*)	(*a*)	(*a*)
Size as used:				
Over $\frac{1}{4}$ inch...per cent..	3.0	3.0	3.0	3.0
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch...do....	8.5	8.5	8.5	8.5
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch...do....	17.0	17.0	17.0	17.0
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch...do....	24.0	24.0	24.0	24.0
Through $\frac{1}{40}$ inch...do....	47.5	47.5	47.5	47.5
Details of manufacture:				
Machine used	Renfrow No. 1.	English.	English.	Renfrow No. 1.
Briquetting temperature, °F	140	176	149	149
Binder—				
Kind	W. G. P.	W. G. P.	W. G. P.	W. G. P.
Laboratory No	4543	4543	4683	4806
Amount...per cent..	7	7	7	8
Weight of—				
Fuel briquetted...pounds..	12,000	12,000	11,000	10,000
Briquets, average...do....	0.460	3.77	3.91	0.442
Drop test (1-inch screen):				
Held...per cent..	64.5	79.7	24.2	34.5
Passed...do....	35.5	20.3	75.8	65.5
Tumbler test (1-inch screen):				
Held...do....	91.5	78.8	43.3	80.5
Passed...do....	8.5	21.2	56.7	19.5
Fines through 10-mesh sieve...do....	94.1	75.7	65.0	87.5
Weather test:				
Time exposed...days..	11	10	....	....
Condition	B	A	....	....
Absorption test:				
Time immersed...days..	19	19	13	13
Water absorbed...per cent..	14.5	9.2	7.4	13.1
Average for first 4 days...do....	2.70	1.60	1.67	1.93
Specific gravity (apparent)	1.053	1.144	1.167	1.123

[a] Screenings.

Chemical analyses of coal and briquets.

	Car sample.	Test 185.	Test 186.	Test 224.	Test 237.
Laboratory No	4376	4397	4382	4830	4890
Proximate:					
Moisture...per cent..	13.10	10.81	14.52	9.17	6.98
Volatile matter...do....	32.16	33.72	33.74	33.03	35.21
Fixed carbon...do....	41.49	42.74	39.40	43.90	42.85
Ash...do....	13.25	12.73	12.34	13.90	14.96
Sulphur...do....	3.66	3.50	3.36	3.90	3.78
Ultimate:					
Hydrogen...do....	4.58	4.54	4.68	4.33	3.57
Carbon...do....	65.95	67.31	67.91	66.14	59.48
Nitrogen...do....	1.19	1.04	1.12	1.01	0.83
Oxygen...do....	8.82	8.92	7.92	8.93	5.67

Extraction analyses.

	Pitches.			Fuel.	Briquets.			
				Ill. No. 31.	Test 185.	Test 186.	Test 224.	Test 237.
Laboratory No	4543	4683	4806	4376	4397	4385	4830	4890
Air-drying loss...per cent..	....	....	....	9.70	8.00	11.10	4.70	2.80
Extract by CS_2 (as received)...per cent..	99.66	89.31	96.90	.44	6.50	6.21	6.72	7.58
Pitch in briquet by analysis...per cent..	....	....	....	....	6.11	5.86	7.08	7.41
Heat value...B. t. u..	16,969	16,637	16,864	10,393	11,002	10,517	10,921	11,158

ILLINOIS NO. 33.

Bituminous-coal screenings, through 1½-inch shaking screen, from bed No. 7 at Trenton, Clinton County, on the Baltimore & Ohio Railroad, were designated Illinois No. 33, and a part of the sample was used in briquetting tests 206, 207, 210, and 235. Steaming test 513 was made of the briquets.

The surfaces of all briquets were soft, their fracture ragged, and their edges easily broken. Greater percentages of binder had no apparent effect on their appearance. Increased moisture content made a very soft, warm briquet, which hardened on cooling with a harder surface than those with less moisture.

Briquetting tests.

	Test 206.	Test 207.	Test 210.	Test 235.
Size as shipped	Screenings.	Screenings.	Screenings.	Screenings.
Size as used:				
Over $\frac{1}{4}$ inch...per cent..	2.0	2.0	2.0	2.0
$\frac{1}{10}$ to $\frac{1}{4}$ inch...do....	9.8	9.8	9.8	9.8
$\frac{1}{20}$ to $\frac{1}{10}$ inch...do....	26.4	26.4	26.4	26.4
$\frac{1}{40}$ to $\frac{1}{20}$ inch...do....	27.0	27.0	27.0	27.0
Through $\frac{1}{40}$ inch...do....	34.8	34.8	34.8	34.8
Details of manufacture:				
Machine used	English.	English.	Renfrow No. 1.	Renfrow No. 1.
Briquetting temperature...° F..	149	149	158	167
Binder—				
Kind	W. G. P.	W. G. P.	W. G. P.	W. G. P.
Laboratory No	4683	4683	4683	4806
Amount...per cent..	7	6	7	8
Weight of—				
Fuel briquetted...pounds..	8,000	7,000	6,000	15,000
Briquets, average...do....	4.07	4.12	0.474	0.484
Drop test (1-inch screen):				
Held...per cent..	50.0	61.8	74.5	34.5
Passed...do....	50.0	38.2	25.5	65.5
Tumbler test (1-inch screen):				
Held...do....	55.6	60.3	94.0	89.5
Passed...do....	44.4	39.7	6.0	10.5
Fines through 10-mesh sieve...do....	66.6	72.1	90.8	94.7
Absorption test:				
Time immersed...days..	10	10	10	10
Water absorbed...per cent..	7.6	9.4	11.1	6.5
Average for first 4 days...do....	2.30	2.40	2.93	1.70
Specific gravity (apparent)	1.291	1.280	1.232	1.298

Chemical analyses of coal and briquets.

	Mine sample.	Tests 206 and 207.	Test 235.
Laboratory No	4385	4728	4888
Proximate:			
Moisture per cent	15.06	11.50	9.47
Volatile matter do	29.48	25.44	28.25
Fixed carbon do	45.81	42.37	40.75
Ash do	9.65	20.69	21.53
Sulphur do	1.05	1.52	1.56
Ultimate:			
Hydrogen do		3.72	3.93
Carbon do		61.46	60.07
Nitrogen do		1.02	1.03
Oxygen do		8.70	9.47

Extraction analyses.

	Pitches.		Fuel.	Briquets.	
			Ill. No. 33.	Tests 206 and 207.	Test 235.
Laboratory No	4683	4806	4385	4728	4888
Air-drying loss per cent			4.80	5.50	3.90
Extract by CS_2 (as received) do	89.31	96.90	.28	4.93	7.42
Pitch in briquet by analysis do				5.23	7.40
Heat value B. t. u.	16,637	16,864	10,726	9,823	9,761

INDIANA NO. 1.

A sample of bituminous run-of-mine coal from Mildred, Sullivan County, on the Evansville & Terre Haute Railroad, was designated Indiana No. 1, and a part of the sample was subjected to briquetting tests at the St. Louis plant.

Four tons of this coal was briquetted in the English press with 7 per cent of pitch D. The coal was first washed and then dried. The briquets were brown in color, readily handled as they came from the machine, and when cold stood rough handling. The average weight of the briquets was 6.8 pounds each. Eggettes made of the mixture on the American machine were better and stronger than the briquets.

Chemical analyses of coal and briquets.

	Car sample.	Briquets.
Laboratory No	1507	1521
Proximate:		
Air-drying loss per cent	3.00	4.20
Moisture do	11.40	11.74
Volatile matter do	33.81	38.79
Fixed carbon do	41.39	43.23
Ash do	13.40	6.24
Sulphur do	2.50	2.03
Ultimate:		
Hydrogen do	4.63	4.91
Carbon do	68.11	75.77
Nitrogen do	1.33	1.47
Oxygen do	7.99	8.48
Heat value B. t. u.	11,061	12,037

INDIANA NO. 1B.

Bituminous screenings (through 1-inch screen) from Mildred, Sullivan County, on the Evansville & Terre Haute Railroad, were designated Indiana No. 1B. The sample was used in briquetting test 217. No steaming test was made of the briquets.

Briquets made with 8.5 per cent of binder on the Renfrow No. 1 machine were satisfactory when the fuel was very dry; excess of moisture made briquets that were soft when warm and crumbled easily when cold. The briquets had a porous, dull surface and a rough fracture with ragged edges, but were tough and hard, producing only a small amount of slack in handling and showing no evidence of sticking together when piled warm. Locomotive and house boiler tests were made of briquets from test 217.

Briquetting test.

	Test 217.		Test 217.
Size as shipped	Screenings.	Drop test (1-inch screen):	
Size as used:		Held ... per cent	54.5
Over 1/4 inch ... per cent	5.0	Passed ... do	45.5
1/10 inch to 1/4 inch ... do	12.4	Tumbler test (1-inch screen):	
1/20 inch to 1/10 inch ... do	22.4	Held ... do	86.5
1/40 inch to 1/20 inch ... do	23.4	Passed ... do	13.5
Through 1/40 inch ... do	36.8	Fines through 10-mesh sieve, per cent	95.0
Details of manufacture:			
Machine used	Renfrow No. 1.	Absorption test:	
Briquetting temperature ... °F	141	Time immersed ... days	22
Binder—		Water absorbed ... per cent	14
Kind	W. G. P.	Average for first 4 days ... do	1.92
Laboratory No	4683	Specific gravity (apparent)	1.114
Amount ... per cent	8.5		
Weight of—			
Fuel briquetted ... pounds	88,000		
Briquets, average ... do	0.485		

Chemical analyses of coal and briquets.

	Car sample.	Test 217.
Laboratory No	4590	4680
Proximate:		
Moisture ... per cent	15.83	8.29
Volatile matter ... do	29.08	30.55
Fixed carbon ... do	39.20	47.01
Ash ... do	15.89	14.15
Sulphur ... do	2.54	2.38
Ultimate:		
Hydrogen ... do	...	4.43
Carbon ... do	...	68.76
Nitrogen ... do	...	1.19
Oxygen ... do	...	7.59

Extraction analyses.

	Pitch.	Fuel.	Briquets.
		Ind. No. 1B.	Test 217.
Laboratory No.	4683	4590	4680
Air-drying loss ... per cent..	....	13.90	3.60
Extracted by CS_2 (as received) ... do....	89.31	.69	7.08
Pitch in briquet, by analysis ... do....	....	....	7.21
Heat value ... B. t. u..	16,637	9,866	11,444

INDIANA NO. 2.

A sample of bituminous run-of-mine coal from Boonville, Warrick County, on the Southern Railway, was designated Indiana No. 2 and a part of the sample was subjected to a briquetting test.

One ton of this coal was briquetted with 7 per cent of pitch H, the briquets being satisfactory in every way. They were brown in color and resembled those made of Indiana No. 1 coal, but were much stronger, by reason of the better quality of pitch. They weighed on the average 6.42 pounds each. No analysis of the briquets was made.

Chemical analysis.

	Car sample.		Car sample.
Laboratory No.	1495	Ultimate:	
Proximate:		Hydrogen ... per cent..	4.71
Air-drying loss ... per cent..	3.60	Carbon ... do....	67.16
Moisture ... do....	9.62	Nitrogen ... do....	1.33
Volatile matter ... do....	36.14	Oxygen ... do....	7.49
Fixed carbon ... do....	41.22	Heat value ... B. t. u..	11,122
Ash ... do....	13.02		
Sulphur ... do....	4.43		

INDIANA NO. 5B.

A sample of bituminous screenings (through 1¼-inch bar screen) from Hymera, Sullivan County, on the Evansville & Terre Haute Railroad, was designated Indiana No. 5B and was used in briquetting tests 229 and 230.

The briquets made were identical in characteristics with those made from Indiana No. 1B and Indiana No. 6B coal.

Locomotive and house-boiler tests were made of the briquets from test 230, but locomotive steaming tests only were made of the briquets from test 229.

Briquetting tests.

	Test 229.	Test 230.
Size as shipped	Screenings.	Screenings.
Size as used:		
Over ¼ inch, per cent	1.0	1.0
1/10 inch to ¼ inch, do.	5.6	5.6
1/20 inch to 1/10 inch, do.	11.8	11.8
1/40 inch to 1/20 inch, do.	20.4	20.4
Through 1/40 inch, do.	61.2	61.2
Details of manufacture:		
Machine used	English.	Renfrow No. 1.
Briquetting temperature, °F.	176	140
Binder—		
Kind	W. G. P.	W. G. P.
Laboratory No.	4806	4806
Amount, per cent	7	9
Weight of—		
Fuel briquetted, pounds	24,000	30,000
Briquets, average, do.	3.69	0.424
Drop test (1-inch screen):		
Held, per cent	81.6	50.0
Passed, do.	18.4	50.0
Tumbler test (1-inch screen):		
Held, do.	79.3	81.5
Passed, do.	20.7	18.5
Fines through 10-mesh sieve, do.	72.5	92.3
Absorption test:		
Time immersed, days	13	23
Water absorbed, per cent	7.4	13.8
Average for first 4 days, do.	1.2	1.86
Specific gravity (apparent)	1.078	1.097

Chemical analyses of coal and briquets.

	Car sample.	Test 229.	Test 230.
Laboratory No.	4708	4822	....
Proximate:			
Moisture, per cent	13.48	7.27	6.34
Volatile matter, do.	31.94	37.73	37.53
Fixed carbon, do.	42.97	44.37	44.74
Ash, do.	11.61	10.63	11.39
Sulphur, do.	4.08	4.29	4.76
Ultimate:			
Hydrogen, do.	4.65	4.49	4.62
Carbon, do.	67.30	68.47	68.06
Nitrogen, do.	1.09	1.13	1.10
Oxygen, do.	8.82	9.80	8.96

Extraction analyses.

	Pitch.	Fuel.	Briquets.	
		Ind. No. 5B.	Test 229.	Test 230.
Laboratory No.	4806	4708	4822	....
Air-drying loss, per cent	....	10.00	....	....
Extracted by CS_2 (as received), do.	96.90	....	6.87	8.50
Pitch in briquet by analysis, do.	....	....	5.82	7.52
Heat value, B. t. u.	16,864	10,822	11,945	12,046

INDIANA NO. 6B.

Bituminous screenings, through 1¼-inch bar screen, from vein No. 4 at Hymera, Sullivan County, on the Evansville & Terre Haute Railroad, were designated Indiana No. 6B, and were used in briquetting tests 220 and 227. A locomotive steaming test was made of briquets from test 220 and a house-boiler steaming test of briquets from test 227.

Renfrow briquets were similar to those made from Indiana No. 1B coal. Seven per cent binder gave satisfactory English briquets when the coal was thoroughly dried; otherwise the briquets were soft and easily broken when cold. When warm, the briquets were soft and spongy, although cohesive enough to be handled without breaking. When cold, they became tough, with porous surfaces, rough fractures, and ragged edges.

Briquetting tests.

	Test 220.	Test 227.
Size as shipped	Screenings.	Screenings.
Size as used:		
Over $\frac{1}{4}$ inch ... per cent	1.2	1.2
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch ... do	5.6	5.6
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch ... do	10.2	10.2
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch ... do	20.4	20.4
Through $\frac{1}{40}$ inch ... do	62.6	62.6
Details of manufacture:		
Machine used	Renfrow No. 1.	English.
Briquetting temperature ... °F	140	168
Binder—		
Kind	W. G. P.	W. G. P.
Laboratory No.	4806	4806
Amount ... per cent	8.5	7
Weight of—		
Fuel briquetted ... pounds	64,000	8,000
Briquets, average ... do	0.484	3.84
Drop test (1-inch screen):		
Held ... per cent	58.5	83.7
Passed ... do	41.5	16.3
Tumbler test (1-inch screen):		
Held ... do	84.0	81.2
Passed ... do	16.0	18.8
Fines through 10-mesh sieve ... do	90.0	78.3
Absorption test:		
Time immersed ... days	13	13
Water absorbed ... per cent	12.5	6.7
Average for first 4 days ... do	2.04	1.06
Specific gravity (apparent)	1.083	1.156

Chemical analyses of coal and briquets.

	Raw fuel.	Test 220.	Test 227.
Laboratory No.	4604	4835	4872
Proximate:			
Moisture ... per cent	11.48	5.84	5.72
Volatile matter ... do	35.63	38.08	37.83
Fixed carbon ... do	40.63	44.22	43.16
Ash ... do	12.26	11.86	13.29
Sulphur ... do	5.08	4.49	4.87
Ultimate:			
Hydrogen ... do	4.79	5.04	4.76
Carbon ... do	66.96	70.61	66.48
Nitrogen ... do	1.13	1.14	1.07
Oxygen ... do	7.53	5.85	8.42

Extraction analyses.

	Pitch.	Fuel.	Briquets.	
		Ind. No. 6B.	Test 220.	Test 227.
Laboratory No.	4806	4604	4835	4872
Air-drying loss, per cent		7.00	3.30	2.70
Extract by CS_2 (as received), do	96.90	.76	8.10	7.47
Pitch in briquet by analysis, do			7.64	6.99
Heat value, B. t. u.	16,864	10,987	12,132	11,839

INDIANA NO. 19.

Bituminous screenings, through 1¼-inch stationary bar screen, from the Brazil Block top bed at Diamond, Parke County, on the Chicago & Eastern Illinois Railroad, were designated Indiana No. 19 and were used in briquetting test 165. Steaming test 464 was made of the briquets; a locomotive steaming test was also made of them.

The briquets made of the dry coal with 8 per cent of binder were hard, with firm surfaces and very rough fracture. With moist coal, satisfactory briquets were made regardless of the percentage of binder used. These briquets had a dull-gray color, due to the presence of a large quantity of clay.

Briquetting test.

	Test 165.		Test 165.
Size as shipped	Screenings.	Drop test (1-inch screen):	
Size as used:		Held, per cent	64.0
Over ¼ inch, per cent	3.6	Passed, do	36.0
$\frac{1}{10}$ inch to ¼ inch, do	12.4	Tumbler test (1-inch screen):	
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch, do	20.0	Held, do	89.0
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch, do	24.0	Passed, do	11.0
Through $\frac{1}{40}$ inch, do	40.0	Fines through 10-mesh sieve, per cent	91.5
Details of manufacture:		Weather test:	
Machine used	Renfrow No. 1.	Time exposed, days	95
Briquetting temperature, ° F	131	Condition	C
Binder—		Absorption test:	
Kind	W.G.P.	Time immersed, days	16
Laboratory No.[a]	3962 4120	Water absorbed, per cent	12.6
Amount, per cent	8	Average for first 4 days, per cent	1.90
Weight of—		Specific gravity (apparent)	1.211
Fuel briquetted, pounds	80,000		
Briquets, average, do	0.562		

[a] Binder contained 6 parts No. 4120 and 1 part No. 3962.

Chemical analyses of coal and briquets.

	Raw fuel.	Test 165.
Laboratory No.	3979	4315
Proximate:		
Moisture, per cent	16.91	4.89
Volatile matter, do	26.85	30.53
Fixed carbon, do	38.87	44.00
Ash, do	17.37	20.58
Sulphur, do	1.89	3.36
Ultimate:		
Hydrogen, do	4.33	4.18
Carbon, do	63.75	61.71
Nitrogen, do	1.22	1.00
Oxygen, do	7.53	7.94

Extraction analyses.

	Pitches.		Fuel.	Briquets.
			Ind. No. 19.	Test 165.
Laboratory No.	3962	4120	3979	4315
Air-drying loss.....per cent..			13.10	5.40
Extract by CS_2 (as received).....do....	77.79	97.70	1.12	7.39
Pitch in briquet by analysis.....do....				6.90
Heat value.....B. t. u..	16,946	16,946	9,524	10,649

INDIANA NO. 20.

Bituminous screenings, through a $1\frac{1}{4}$-inch bar screen, from the Brazil Block bottom bed at Brazil, Clay County, on the Chicago & Eastern Illinois Railroad, were designated Indiana No. 20, and a part of the washed sample was used in briquetting test 169. A locomotive steaming test was made of the briquets.

The surfaces of briquets with 7 per cent of binder became soft and easily abraded as the briquets cooled. The briquets were easily transported from the press, but produced a high percentage of slack when handled afterwards. Their fracture was rough and their color brighter than in briquets from unwashed fuel.

Briquetting test.

	Test 169.		Test 169.
Size as shipped	Screenings.	Drop test (1-inch screen):	
Size as used:		Held.....per cent..	39.0
Over $\frac{1}{4}$ inch.....per cent..	0.0	Passed.....do....	61.0
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch.....do....	3.0	Tumbler test (1-inch screen):	
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch.....do....	16.2	Held.....per cent..	71.0
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch.....do....	26.6	Passed.....do....	29.0
Through $\frac{1}{40}$ inch.....do....	54.2	Fines through 10-mesh sieve, per cent	93.8
Details of manufacture:			
Machine used	Renfrow No. 1.	Weather test:	
Briquetting temperature..°F..	131	Time exposed.....days..	48
Binder—		Condition	B
Kind	W. G. P.	Absorption test:	
Laboratory No.	4318, 4543	Time immersed.....days..	19
Amount.....per cent..	7	Water absorbed.....per cent..	28.5
Weight of—		Average for first 4 days..do....	4.0
Fuel briquetted..pounds..	30,000	Specific gravity (apparent)	0.903
Briquets, average...do....	0.427		

Chemical analyses of coal and briquets.

	Raw fuel.	Test 169.
Laboratory No.	3979	4627
Proximate:		
Moisture.....per cent..	16.91	9.67
Volatile matter.....do....	26.85	35.75
Fixed carbon.....do....	38.87	47.65
Ash.....do....	17.37	6.93
Sulphur.....do....	1.89	1.40
Ultimate:		
Hydrogen.....do....	4.33	5.06
Carbon.....do....	63.75	75.14
Nitrogen.....do....	1.22	1.25
Oxygen.....do....	7.53	9.33

Extraction analyses.

	Pitches.		Fuel.	Briquets.
			Ind. No. 20.	Test 169.
Laboratory No.	4318	4543	3979	4627
Air-drying loss ... per cent.			13.10	7.90
Extracted by CS_2 (as received) ... do.	90.42	99.66	.63	8.40
Pitch in briquet, by analysis ... do.				8.39
Heat value ... B. t. u.	16,811	16,811	9,524	12,391

INDIAN TERRITORY NO. 2.

A sample of bituminous run-of-mine coal from Hartshorne, Pittsburg County, Okla. (Indian Territory on the date test was made), on the Rock Island system, was designated Indian Territory No. 2, and a part of the sample was subjected to briquetting tests.

This coal was tested with the hard pitch X. With 8.5 per cent of pitch the briquets were not strong and crumbled readily. With 12 per cent of pitch the briquets were not much better, and with 13.4 per cent they looked well as they came from the press but were not strong and began to lose their corners soon after being exposed to the weather. Judging from the runs made, this coal will require more than the usual pressure. The briquets containing 8.5 per cent of pitch weighed only 5.08 pounds each. Those with 13.4 per cent of pitch weighed 6.15 pounds each.

Chemical analysis.

	Car sample.		Car sample.
Laboratory No.	1184	Ultimate:	
Proximate:		Hydrogen ... do.	4.90
Air-drying loss ... per cent.	2.80	Carbon ... do.	72.73
Moisture ... do.	4.45	Nitrogen ... do.	1.75
Volatile matter ... do.	36.15	Oxygen ... do.	7.52
Fixed carbon ... do.	48.40	Heat value ... B. t. u.	12,607
Ash ... do.	11.00		
Sulphur ... do.	1.52		

INDIAN TERRITORY NOS. 2B AND 2C.

Bituminous slack screenings, through a ⅜-inch shaking screen, from the Hartshorne bed at Hartshorne, on the Rock Island Railroad, were designated Indian Territory No. 2B, and a part of this sample was used in briquetting tests 135, 136, 137, 138, 139, 145, 146, 147, 148, 149, 157, and 168. Steaming tests 453 and 456 were made of the briquets from briquetting tests 137, 148, and 157. Locomotive steaming tests were also made of briquets from briquetting tests 148 and 149. House-boiler steaming tests were made of briquets from tests 148 and 157.

Bituminous lump coal, over 1-inch shaking screen, from the same locality as Indian Territory No. 2B coal, was designated Indian Teirrtory No. 2C, and a part of the sample was used in briquetting tests 153, 154, 155, and 156. No steaming tests or locomotive or house-boiler tests were made of briquets from this sample.

In tests 135, 136, 137, 145, 146, 147, 148, and 168, with Indian Territory No. 2B raw slack coal, there was no apparent difference in English briquets with 6, 7, and 8 per cent of binder. A small lot with 5 per cent of binder showed shortage of pitch. The pressure on the machine was changed during the making of Renfrow briquets, as indicated in the results of the tests. All briquets were satisfactory, having sharp edges, hard surfaces, and clean, rough fracture; they could be handled while warm from the machine and could be piled 5 feet high without sticking together or crushing.

Briquetting tests of Indian Territory No. 2B coal.[a]

	Test No.							
	135.	136.	137.	145.	146.	147.	148.	168.
Details of manufacture:								
Machine used	English.	English.	English.	English.	English.	English.	Renfrow No. 1.	Renfrow No. 1.
Briquetting temperature (°F.)	185	185	185	185	185	185	149	149
Binder—								
Kind	W. G. P.	W. G. P.	W. G. P.	W. G. P.	W. G. P.	W. G. P.	W. G. P.	W. G. P.
Laboratory No.	3258	3258	3296	3486	3623	3624	3486	3296
Amount, per cent	6	7	8	6	7	8	8	8
Weight of—								
Fuel briquetted. lbs	11,000	22,000	70,000	16,000	16,000	16,000	19,400	99,000
Briquets, average. lbs	3.46	3.88	3.77	3.53	3.64	3.43	0.515	0.508
Drop test (1-inch screen):								
Held...per cent	....	....	....	81.7	82.8	84.2	58.5	....
Passed.....do	....	....	....	18.3	17.2	15.8	41.5	....
Tumbler test (1-inch screen):								
Held...per cent	....	74.8	....	73.3	79.8	80.8	81.0	....
Passed.....do	....	25.2	....	26.7	20.2	19.2	19.0	....
Fines through 10-mesh sieve, per cent	....	75.0	....	86.5	85.6	75.5	95.4	....
Weathering test:								
Time exposed, days	239	239	239	145	145	145	144	239
Condition	B	C	B	B	A	A	B	B
Absorption test:								
Time immersed, days	....	....	....	16	16	16	16	....
Water absorbed, per cent	....	....	....	8.6	10.2	11.4	12.9	....
Average for first 13 days, per cent	....	....	....	1.62	.72	.84	....	....
Average for first 6 days, per cent	....	....	....	....	....	....	1.7	....
Specific gravity (apparent)	....	....	....	1.151	1.133	1.076	1.117	....

[a] Raw slack.

As stated above, tests 138, 139, 149, and 157 were made with Indian Territory No. 2B washed slack coal, and tests 153, 154, 155, and 156 with Indian Territory No. 2C lump coal. Tests 138 and 139 were made with the first sample sent to the plant and tests 149 and 157 with the second sample. Excellent briquets were made with 8 per cent of binder. The English briquets showed the advantage of higher pressure by being harder and closer grained and having smoother surfaces and sharper edges. Similar differences marked the superiority of these briquets over those made from the same slack unwashed.

The briquets made from the lump coal (Indian Territory No. 2B) may be considered as standing in value between those made from washed and those made from unwashed slack from the same mine; they are identical in appearance.

Briquetting tests with Indian Territory No. 2B [a] and Indian Territory No. 2C [b] coal.

	Test No.							
	138.	139.	149.	157.	153.	154.	155.	156.
Details of manufacture:								
Machine used	English.	Renfrow No. 1.	Renfrow No. 1.	English.	English.	English.	English.	Renfrow No. 1.
Briquetting temperature (°F.)	185	149	149	185	185	185	185	149
Binder—								
Kind	W. G. P.	W. G. P.	W. G. P.	W. G. P.	W. G. P.	W. G. P.	W. G. P.	W. G. P.
Laboratory No.	3624	3296	3624	3624	3486	3486	3486	3486
Amount, per cent	8	8	8	8	6	7	8	8
Weight of—								
Fuel briquetted . lbs	16,000	20,000	40,000	8,000	1,000	1,000	1,000	8,000
Briquets, average, lbs	3.31	0.451	0.476	3.34	3.11	3.19	3.14	0.490
Drop test (1-inch screen):								
Held . . . per cent	88.9	60.0	56.0	85.5	79.8	84.6	86.4	70.0
Passed . . . do	11.1	40.0	44.0	14.5	20.2	15.4	13.6	30.0
Tumbler test (1-inch screen):								
Held . . . per cent	85.0	79.0	76.0	82.5	71.0	76.6	83.5	81.5
Passed (fines), per cent	15.0	21.0	24.0	17.5	29.0	23.4	16.5	18.5
Fines through 10-mesh sieve, per cent	79.5	90.5	93.7	78.1	82.3	80.6	78.4	90.9
Weathering test:								
Time exposed, days	128	127	149	128	239	239	239	182
Condition	B	C	B	A	C	C	C	B
Absorption test:								
Time immersed, days	19	19	19	19	19	19	15	19
Water absorbed, per cent	9.6	14.7	16.0	10.3	12.6	11.1	10.2	13.5
Average for first 5 days, per cent	1.20	2.0	2.26	1.06	....	1.34	1.57	1.84
Average for first 12 days, per cent	....	....	....	....	0.93	....	....	....
Specific gravity (apparent)	1.097	1.061	1.024	1.096	1.070	1.084	1.088	1.077

[a] Washed slack.

[b] Lump.

Chemical analyses of raw fuel and briquets.

	Raw fuel.	Raw fuel.	Tests 135 and 136.	Test 137.	Tests 138 and 157.
Laboratory No	3381	3472	3262	3342	4108
Proximate:					
Moisture .... per cent	3.77	5.69	3.61	3.85	2.8
Volatile matter .... do	32.65	32.45	33.03	34.06	34.91
Fixed carbon .... do	51.15	48.76	49.64	49.36	54.0
Ash .... do	12.43	13.10	13.72	12.73	8.21
Sulphur .... do	1.79	1.67	1.76	1.71	1.50
Ultimate:					
Hydrogen .... do	4.77	4.53	4.65	4.54	4.87
Carbon .... do	72.37	72.05	71.08	73.17	76.29
Nitrogen .... do	1.77	1.80	1.46	1.61	1.71
Oxygen .... do	6.31	5.96	6.75	5.66	7.1

	Test 139.	Tests 145, 146, and 147.	Test 148.	Test 149.	Test 168.
Laboratory No	3896	3520	4086	3559	334
Proximate:					
Moisture .... per cent	2.80	2.87	3.29	2.13	3.8
Volatile matter .... do	35.67	35.02	35.25	36.97	34.0
Fixed carbon .... do	53.77	50.60	53.15	54.14	49.3
Ash .... do	7.76	11.51	8.31	6.76	12.7
Sulphur .... do	1.58	1.72	1.52	1.47	1.71
Ultimate:					
Hydrogen .... do	4.91	4.48	4.93	5.04	4.5
Carbon .... do	75.63	73.39	76.11	77.98	73.1
Nitrogen .... do	1.52	1.49	1.69	1.78	1.61
Oxygen .... do	8.33	7.02	7.11	6.79	5.6

Extraction analyses.

	Fuels.		Briquets.				
	Ind. T. No. 2B.	Ind. T. No. 2C.	Tests 135 and 136.	Test 137.	Tests 138 and 157.	Test 139.	Tests 145 146, and 147.
Laboratory No	3381	3472	3262	3342	4108	3896	352
Air-drying loss .... per cent	1.50	3.80	1.50	....	0.90	1.20	1.0
Extracted by CS_2 (as received), per cent	.32	.41	4.72	6.32	6.04	7.58	8.7
Pitch in briquet by analysis, per cent	....	....	5.50	7.32	6.32	8.75	10.1
Heat value .... B. t. u.	12,400	12,033	12,317	12,481	13,562	13,541	12,81

	Pitches.				Briquets.		
					Test 148.	Test 149.	Test 168.
Laboratory No	3624	3296	3486	3258	4086	3559	334
Air-drying loss .... per cent	....	....	....	....	1.30	0.50	....
Extracted by CS_2 (as received), per cent	89.60	82.43	85.57	80.27	6.00	6.40	8.8
Pitch in briquet by analysis, per cent	....	....	....	....	6.57	6.22	10.4
Heat value .... B. t. u.	16,193	16,427	16,407	16,373	13,412	13,707	12,48

INDIAN TERRITORY NO. 3.

A sample of bituminous run-of-mine coal from Edwards, Ind. T (now Oklahoma), on the Rock Island Railroad, was designate Indian Territory No. 3, and a part of the sample was subjected t briquetting tests at the St. Louis plant.

This coal, which is hard and glossy, was tested on the English machine with 8 per cent of pitch A. The mixture made fairly good briquets, which were clean and hard, although somewhat porous, but they were not so strong as was desired. This defect was due in part to lack of sufficient heat to soften the pitch thoroughly in the pug mill. The briquets as received from the machine weighed 6.56 pounds each. With 7.2 per cent of pitch A, this coal made smooth and fairly hard briquets, which weighed 6.71 pounds each. With 6 per cent of pitch A, briquets were made that were smooth and well pressed, but soft. These averaged in weight 6.8 pounds each. If the pitch could have been heated in the English machine to a temperature sufficiently high to cause it to soften and mix with the coal the mixture would undoubtedly have made a good briquet, because with a soft pitch, as pitch D or pitch H, this coal could be briquetted with 6 per cent of binder.

Chemical analysis.

	Car sample.		Car sample.
Laboratory No.	1274	Ultimate:	
Proximate:		Hydrogen ... per cent..	4.62
Air-drying loss ... per cent..	1.20	Carbon ... do....	70.62
Moisture ... do....	4.61	Nitrogen ... do....	1.55
Volatile matter ... do....	37.00	Oxygen ... do....	7.72
Fixed carbon ... do....	47.25	Heat value ... B. t. u..	12,319
Ash ... do....	11.14		
Sulphur ... do....	3.63		

INDIAN TERRITORY NO. 6.

A sample of bituminous slack coal from Coalgate, Ind. T. (now Oklahoma), on the Missouri, Kansas & Texas Railway, was designated Indian Territory No. 6, and a part of the sample was subjected to briquetting tests at the St. Louis plant.

The sample consisted of a carload of dirty slack which contained considerable fire clay and some shale. Laboratory experiments had shown that 7 per cent of a binder of the quality of pitch D was the minimum that could be expected to give satisfactory results. Accordingly, 1 ton of this coal was mixed by hand with 7 per cent of pitch D, but the briquets were crumbly and not at all satisfactory, although dense and well pressed. They weighed 7.35 pounds each. They were full of gray streaks on the surface, due to the fire clay, and on standing became coated with a heavy gray efflorescent substance which was found to be calcium sulphate. Eggettes of this same mixture made on the American machine were practically the same in character and unusually dull gray in appearance. The specific gravity of the briquets was 1.205. When tested on the compression machine these briquets, which were crumbly and weak and broke easily in the hands, compressed much more than usual before breaking. Their crushing strength was 5,600 pounds, or 195 pounds per square inch. Another ton was tried with 9 per cent of pitch D, but the briquets were practically the same as with 7 per cent, although a little darker in color. They also showed similar streaks of fire clay on the surface and their fracture was decidedly earthy. They weighed on the average 7.5 pounds each. There seems to have been little adhesiveness between this pitch and the dirty coal, and to make good briquets with this pitch it would probably be necessary to use as much as 15 per cent, if not more.

Satisfactory results with soft pitch not having been obtained, 1 ton of the slack coal was tried with 8 per cent of the harder pitch A. The briquets were well pressed and blacker than those with 7 per cent of pitch D, but were not so strong. The mixture did not show any tendency to stiffen in the machine. All of the tests with this coal demonstrated its injurious effect on the binding properties of the pitch.

The coal was next tried by mixing together 93 per cent of coal, 6 per cent of rosin, and 1 per cent of quicklime. The lime was mixed in sizes ranging from dust to pieces three-fourths of an inch in diameter, and it was thought that the lumps would be reduced by the disintegrator and the lime slaked by the steam of the pug mill, so that the cement would not set too quickly. The disintegrator, however, had little effect on the hard lime, and consequently there were in the briquets many large unslaked pieces, which caused the briquets to fall to pieces. Some of the material that remained in the pug mill for some time gave a briquet that was hard while hot, but after cooling became earthy. The briquets weighed on an average 7 pounds each. The eggettes made of this material were dense but crumbly.

In order to prevent unslaked lime from going into the briquets, the lime before being used was slaked with one-half its weight of water, making a fine, dry powder. This was mixed with the coal to give the same proportions with the rosin as in the above test, and although the briquets were smooth and well formed, having been thoroughly pressed, they were crumbly and not at all strong. They were grayish in color and similar in quality to those made with 7 per cent of pitch D. They weighed on an average 7.5 pounds each. The eggettes of this same material were also crumbly and dull in luster.

Some of the lime-rosin briquets were burned and gave less smoke than those with the rosin and no lime, some giving even less than the briquets made with pitch alone.

Another test of this coal was made with rosin and Kansas crude oil. The experiments in the laboratory had shown that the best results could be obtained by using 6 per cent of rosin and 1 per cent of the oil. In preparing this combination for the English machine the oil was first mixed with five times its weight of fine coal, so as to make a nonsticky mass that would readily mix with the cracked rosin and coal in the usual manner. As the rosin became very fluid at 212° F. the hot briquets when received from the machine had no strength, and cracked slightly under their own weight when piled only two high. They also cracked somewhat because of the water in the wet steam. On cooling they became strong and were of good quality. Some of the mixture that was allowed to stand in the mold until cool enough to be "tacky" before pressing was good as received from the machine, but it had not been sufficiently compacted. On standing, these briquets became coated with a heavy brownish-gray efflorescence. The weight of these briquets averaged 7.29 pounds each and their specific gravity was 1.25. The crushing strength of the briquets was on the average 6,400 pounds, or 223 pounds per square inch. On account of the lack of uniformity of the briquets, however, the results of eight tests varied from 4,300 to 9,240 pounds. The eggettes made from this same mixture were hard and compact, although of a dull color, and they had a good degree of strength as received from the machine. With an arrangement for cooling the mass after it had passed through the pug mill and before being fed to the press this mixture made briquets that were very good physically, but smoked rather badly.

As the above tests showed that the best way to counteract the effect of the large amount of fire clay in this coal was to add some liquid binder that would soak into the coal and at the same time unite with the solid binder, another test was made with creosote as a liquid binder and pitch as the hard binder. For this purpose Indian Territory No. 6 coal was mixed with 8 per cent of pitch G and 1¼ per cent of creosote such as is used in preserving timber. The creosote and five times its weight of fine coal were first mixed together and then thoroughly mixed with the cracked pitch and coal. In operating the machine the amount of steam used for heating the mixture was gradually increased until there was an excess. This, however, had no effect upon the cooled briquets, but it made the hotter ones more tender and a little harder to handle. The first briquets of this mixture cracked a little, because of excess of water, but the remainder came from the machine strong enough to bear handling at once. The effect of the excess of steam was to insure more complete softening of the pitch and more uniform mixing of the clay. The briquets were black and clean and only slightly streaked with the clay. When piled they stuck together slightly, and were mottled a little from the creosote. However, they showed much less of the gray efflorescent substance than any of the Indian Territory No. 6 briquets and were also the best made, although earthy. They were smooth and black, and although crumbling little or not at all in handling, they would crumble a great deal on breaking or firing. On the other hand, the eggettes, made of this same mixture on the American machine, were just as strong and would need no breaking in firing. The weight of the briquets was 7.25 pounds each on an average. Their specific gravity was 1.215 and their crushing strength was 6,500 pounds, or 226 pounds to the square inch.

Another test with the Indian Territory No. 6 coal was made with asphalt B5, which during the cool weather had become hard enough to crack, and thus could be readily used on the English machine. One ton of this coal with 8 per cent of asphalt made soft briquets that were hard to handle while warm, especially when they contained moisture due to the wet steam. The better ones were compact, heavy, and tough, and although they had an earthy, oily appearance, did not crack when struck a severe blow. They would stand rough handling, but would be improved with a small percentage of rosin. The briquets weighed 7.12 pounds each, and had a specific gravity of 1.22. Their crushing strength was very low, averaging 3,200 pounds, or 111 pounds per square inch. It varied from 1,800 to 5,100 pounds. In making the compression tests the briquets yielded a great deal before breaking.

A sample of pitch H was tried with the Indian Territory No. 6 coal. The best results were obtained with this as a binder. One ton of coal was mixed with 8 per cent of pitch H, and with nearly dry steam and good pressure the mixture made hard, compact briquets. Although somewhat earthy, they would stand rough handling. Their average weight was 7.27 pounds each.

Proximate analysis.

	Car sample.		Car sample.
Laboratory No.	1596	Fixed carbon .... per cent	41.40
Air-drying loss .... per cent	3.50	Ash .... do	19.29
Moisture .... do	8.03	Sulphur .... do	3.20
Volatile matter .... do	31.28		

INDIAN TERRITORY NO. 9.

Semibituminous run-of-mine coal from Panama, on the Kansas City Southern Railroad, was designated Indian Territory No. 9, and a part of the sample was used in briquetting test 167. Steaming test 450 was made of the briquetted fuel.

Excellent briquets were made with 7 per cent of pitch, a quantity that might be reduced if more pressure were used. The briquets were hard, with smooth surfaces and glossy, clean fracture; they were easily handled while hot from the machine, but became somewhat brittle when cold.

Briquetting test.

	Test 167.		Test 167.
Size as used:		Drop test (1-inch screen):	
Over $\frac{1}{4}$ inch per cent	0.8	Held per cent	62.5
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch do	3.6	Passed do	37.5
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch do	12.6	Tumbler test (1-inch screen):	
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch do	25.2	Held do	82.5
Through $\frac{1}{40}$ inch do	57.8	Passed do	17.5
Details of manufacture:		Fines through 10-mesh sieve, per cent	93.0
Machine used	Renfrow No. 1.		
Briquetting temperature °F	176	Weather test:	
Binder—		Time exposed days	31
Kind	W. G. P.	Condition	B
Laboratory No.	4120	Absorption test:	
Amount per cent	7	Time immersed days	18
Weight of—		Water absorbed per cent	16.6
Fuel briquetted pounds	70,000	Average for first 4 days do	2.62
Briquets, average do	0.459	Specific gravity (apparent)	1.090

Chemical analyses of coal and briquets.

	Car sample.	Test 167.
Laboratory No.	4020	4325
Proximate:		
Moisture per cent	5.11	3.39
Volatile matter do	13.65	17.15
Fixed carbon do	73.21	72.04
Ash do	8.03	7.42
Sulphur do	1.18	1.15
Ultimate:		
Hydrogen do	4.30	4.23
Carbon do	82.59	82.89
Nitrogen do	1.69	1.61
Oxygen do	1.72	2.40

Extraction analyses.

	Pitch.	Fuel.	Briquets.
		Ind. T. No. 9.	Test 167.
Laboratory No.	4120	4020	4325
Air-drying loss per cent		4.50	0.90
Extracted by CS_2 (as received) do	97.70	.48	6.14
Pitch in briquet by analysis do			5.83
Heat value B. t. u.	17,060	13,662	14,103

IOWA NO. 4.

A sample of bituminous coal, over 1$\frac{3}{8}$-inch screen, from Centerville, Appanoose County, on the Chicago, Burlington & Quincy Railroad, and four other railroads, was designated Iowa No. 4, and a portion of the sample was subjected to briquetting tests at the St. Louis plant.

One ton of this coal was briquetted with 7 per cent of pitch E. The briquets were well pressed and of a grayish color, but on cooling crumbled decidedly. They weighed 6.73 pounds each. As they did not contain an excess of pitch, 7 tons more of this coal was briquetted with 8 per cent of pitch E, in order to have a sufficient quantity for a steaming test. The resultant briquets were bluish black in color, but were not quite hard enough, although fairly strong; they would stand considerable rough treatment in transportation. In burning they held together until consumed. They weighed on an average 6.77 pounds each. The eggettes made from this same mixture were stronger than the briquets, had a polished surface, but were very brown in color. In the cookstove they burned satisfactorily, crumpling little until consumed. The steaming test made of these briquets gave considerably better results than the original coal, indicating that the coal had been much improved by briquetting.

Chemical analyses of coal and briquets.

	Car sample.	Briquets.		Car sample.	Briquets.
Laboratory No	1437	1488	Ultimate:		
Proximate:			Hydrogen......per cent..	4.67	4.81
Air-drying loss..per cent..	4.50	3.90	Carbon.............do....	68.07	69.25
Moisture...........do....	14.08	13.24	Nitrogen...........do....	1.05	.86
Volatile matter....do....	35.59	36.50	Oxygen.............do....	8.49	6.28
Fixed carbon......do....	39.37	37.85	Heat value...........B. t. u..	10,723	10,885
Ash................do....	10.96	12.41			
Sulphur...........do....	4.26	3.90			

KANSAS NO. 2.

A sample of bituminous lump and nut coal from Yale, Crawford County, on the Missouri Pacific Railroad, was designated Kansas No. 2, and a part of the sample was subjected to briquetting tests at the St. Louis plant.

Two tons of this coal was briquetted with 11 per cent of pitch X. The pitch of the mixture, in passing through the machine from the pug mill to the press, set so quickly that the briquets did not receive the necessary pressure. The surface was rough, and a great many cracks developed. No more of this coal was available for briquetting after the receipt of pitch of the better qualities. It is, however, a coal that will briquet very readily with pitch of the better grades, such as pitch D or pitch H. About 7 per cent of either would be required for commercial briquets.

Chemical analysis.

	Car sample.		Car sample.
Laboratory No	1122	Ultimate:	
Proximate:		Hydrogen.................per cent..	4.41
Air-drying loss............per cent..	2.00	Carbon.......................do....	64.58
Moisture.......................do....	4.18	Nitrogen.....................do....	.96
Volatile matter...............do....	31.23	Oxygen.......................do....	4.82
Fixed carbon..................do....	46.68	Heat value....................B. t. u..	11,642
Ash...........................do....	17.91		
Sulphur.......................do....	6.27		

KANSAS NO. 2B.

Bituminous slack coal, from the lower Weir-Pittsburg bed at Yale, Crawford County, was designated Kansas No. 2B and was used in briquetting tests 182, 183, 194, 195, 199, 203, and 204. The briquets were used in steaming tests 487, 488, and 495, and in locomotive and house-boiler steaming tests.

In tests 182, 183, and 199 raw slack was used as follows: Over one-fourth inch, 1 per cent; one-tenth inch to one-fourth inch, 4.8 per cent; one-twentieth inch to one-tenth inch, 12.6 per cent; one-fortieth inch to one-twentieth inch, 23.6 per cent; through one-fortieth inch, 58 per cent. The briquets showed the same characteristics as those made from washed coal, except that they were harder when cold, and had a harder and rougher fracture, owing to high ash content.

In tests 194, 195, 203, and 204 washed slack was used as follows: Over one-fourth inch, 0.8 per cent; one-tenth inch to one-fourth inch, 4.8 per cent; one-twentieth inch to one-tenth inch, 12.6 per cent; one-fortieth inch to one-twentieth inch, 21.4 per cent; through one-fortieth inch, 60.4 per cent. Satisfactory English briquets were made with 7 per cent of binder, and satisfactory Renfrow briquets with 8 and 9 per cent of binder, there being no apparent difference in these two kinds. Briquets with either had smooth outer surfaces, were well molded, with sharp edges, clean, rough fracture, and did not break in handling while warm. After the briquets became cold those with 9 per cent of binder showed less effect of abrasion than those with 8 per cent of binder. Renfrow briquets showed deficiency of pressure.

Briquetting tests.

	From raw slack.			From washed slack.			
	Test 182.	Test 183.	Test 199.	Test 194.	Test 195.	Test 203.	Test 204.
Details of manufacture:							
Machine used	(a)	(b)	(b)	(a)	(a)	(b)	(b)
Temperature of briquets, ° F.	158	149	149	176	176	149	149
Binder—							
Kind	W. G. P.	W. G. P.	W. G. P.	W. G. P.	W. G. P.	W. G. P.	W. G. P.
Laboratory No	4543	4543	4683	4543	4683	4683	4683
Amount, per cent	7	7	8	7	7	8	9
Weight of—							
Fuel briquetted, pounds	40,000	40,000	68,000	12,000	24,000	16,000	24,000
Briquets, average, pounds	3.95	0.482	0.455	3.65	3.61	0.441	0.417
Drop test (1-inch screen):							
Held, per cent	89.1	69.0	61.0	84.9	81.4	64.0	52.5
Passed, per cent	10.9	31.0	39.0	15.1	18.6	36.0	47.5
Tumbler test (1-inch screen):							
Held, per cent	85.2	91.0	88.5	80.8	83.5	84.5	80.5
Passed (fines), per cent	14.8	9.0	11.5	19.2	16.5	15.5	19.5
Fines through 10-mesh sieve, per cent	71.6	94.7	97.5	87.2	74.6	94.7	94.3
Weathering test:							
Time exposed, days	12	12	....	4	3	....	....
Condition	B	A	....	A	A	....	....
Absorption test:							
Time immersed, days	19	19	13	13	13	13	13
Water absorbed, per cent	9.2	12.6	12.4	8.7	9.7	13.6	12.9
Average for first 4 days, per cent	1.15	1.95	2.23	1.35	1.43	2.50	2.23
Specific gravity (apparent)	1.198	1.170	1.143	1.122	1.105	1.044	1.098

[a] English.

[b] Renfrow No. 1.

Chemical analyses of coal and briquets.

	Car sample.	Raw fuel.	Test 182.	Test 183.	Test 199.
Laboratory No	4361	4518	4374	4380	4665
Proximate:					
Moisture per cent	8.01	9.53	9.43	4.64	2.78
Volatile matter do	26.39	....	29.71	28.40	31.67
Fixed carbon do	45.22	....	43.67	46.56	46.78
Ash do	20.38	10.87	17.19	20.40	18.77
Sulphur do	4.70	3.80	4.15	4.49	4.36
Ultimate:					
Hydrogen do	4.15	....	4.28	5.03	4.35
Carbon do	63.62	....	66.12	64.05	66.00
Nitrogen do	1.13	....	1.03	1.20	.96
Oxygen do	3.83	....	5.01	3.62	4.89

	Test 194.	Test 195.	Test 203.	Test 204.
Laboratory No	4422	4660	4654	4655
Proximate:				
Moisture per cent	7.64	4.23	2.89	3.20
Volatile matter do	32.49	32.64	33.04	33.95
Fixed carbon do	51.52	53.57	52.26	51.53
Ash do	8.35	9.56	11.81	11.32
Sulphur do	3.60	3.36	3.84	3.82
Ultimate:				
Hydrogen do	4.61	4.81	4.32	4.55
Carbon do	74.58	76.20	72.13	73.25
Nitrogen do	1.25	1.20	1.09	1.12
Oxygen do	6.62	4.34	6.33	5.40

Extraction analyses.

	Fuel.		Briquets.		
	Car sample.	Raw fuel.	Test 182.	Test 183.	Test 199.
Laboratory No	4361	4518	4374	4380	4665
Air-drying loss per cent	6.60	8.20	7.00	3.00	....
Extracted by CS_2 (as received) do	0.47	0.54	6.62	6.78	6.61
Pitch in briquet by analysis do	....	....	6.21	6.36	6.91
Heat value B. t. u.	10,640	13,243	11,043	11,221	11,795

	Pitches.		Briquets.			
			Test 194.	Test 195.	Test 203.	Test 204.
Laboratory No	4543	4683	4422	4660	4654	4655
Air-drying loss per cent	....	....	6.20	....	....	....
Extracted by CS_2 (as received) do	99.66	89.31	6.70	6.60	7.02	7.83
Pitch in briquet by analysis do	....	....	6.30	6.83	7.30	8.21
Heat value B. t. u.	16,969	16,637	12,841	12,982	13,012	13,104

KENTUCKY NO. 1.

A sample of bituminous run-of-mine coal from Straight Creek, Bell County, on the Louisville & Nashville Railroad, was designated Kentucky No. 1, and a part of the sample was subjected to briquetting tests at the St. Louis plant.

This is a good coking coal, unusually light in weight and lustrous. In passing through the disintegrator it was ground a little too fine, even when only one side of the machine was used. Furthermore, on account of its light weight it was difficult to obtain the right pressure on the English machine. The coal was tested with 6 per cent of pitch D, the briquets being clean and black, but not sufficiently pressed to fill all the pores. They were, however, good briquets, and would stand rough treatment in transportation. They stood weathering with little change. They weighed on an average 6.15 pounds each. The eggettes made from the mixture were smooth and lustrous and as strong as any eggettes made on the American machine. In the cookstove they burned satisfactorily without disintegrating or giving off an excess of smoke. This coal can be briquetted readily.

Chemical analysis.

	Car sample.		Car sample.
Laboratory No.	1474	Ultimate:	
Proximate:		Hydrogen....per cent..	5.25
Air-drying loss....per cent..	1.20	Carbon....do....	79.85
Moisture....do....	3.10	Nitrogen....do....	1.89
Volatile matter....do....	36.12	Oxygen....do....	7.22
Fixed carbon....do....	56.39	Heat value....B. t. u..	14,148
Ash....do....	4.39		
Sulphur....do....	1.22		

KENTUCKY NO. 2.

A sample of bituminous coal, over ⅞-inch screen, from Earlington, Hopkins County, on the Louisville & Nashville Railroad, was designated Kentucky No. 2, and a part of the sample was subjected to briquetting tests on both the English and the American machines at the St. Louis plant.

As none of the good pitches was available at the time this coal was tested, it was briquetted on the English machine with 9 per cent of pitch E, the necessary percentage as determined by laboratory work. Three tons of this coal was tested. The briquets were extremely pitchy, and, on account of excessive water due to wet steam, were difficult to handle, and when piled three or four deep crushed under their own weight. With dry steam the briquets were more easily handled. Although somewhat plastic, they did not crush when piled. On cooling, the briquets were hard, with lustrous fracture, and were capable of standing a great deal of rough handling. They weighed on an average 6.83 pounds each. The eggettes made of the mixture were hard, but almost too brittle. In the cookstove the eggettes burned satisfactorily.

The coal was tested with 8 per cent of pitch E, 3½ tons of coal being used and the briquets being given the greatest pressure possible on the English machine. As the coal is hard, and as only one side of the disintegrator was used, there were many large pieces of coal in the briquets, but there were also sufficient small pieces to fill in all the openings between the larger fragments. This is nearly an ideal condition for briquetting on the English machine. The briquets were bluish black and excellent in every way. They did not have the glossy or lustrous fracture of the briquets containing 9 per cent of pitch, but they were a better commercial briquet and were more easily handled when taken from the machine. With pitch of the quality of pitch D or pitch H, 5 to 6 per cent would make a good briquet. The briquets tested would stand much rough treatment in transportation. They did not disintegrate in burning, nor was there much slack formed in breaking them for burning. They weighed on an average 6.83 pounds each and had a specific gravity of 1.13, as compared with 1.37 for the slack or fine coal. The slack that was used in making the briquets contained 18 per cent of ash, but the lump coal contained only 11 per cent of ash. The crushing strength of the briquets was 11,300 pounds, or 394 pounds per square inch.

The results of the steaming test of the briquets showed that the briquets have no greater efficiency than the original coal.

The eggettes made from this same mixture were stronger and better than those made with 9 per cent of pitch, although not so hard. They were also browner in color. The eggettes were not so strong as the briquets.

Chemical analyses of coal and briquets.

	Car sample.	Briquets.
Laboratory No.	1461	1544
Proximate:		
Air-drying loss . . . per cent.	2.70	3.30
Moisture . . . do.	7.91	7.11
Volatile matter . . . do.	37.94	37.07
Fixed carbon . . . do.	45.02	44.31
Ash . . . do.	9.13	11.51
Sulphur . . . do.	3.62	3.71
Ultimate:		
Hydrogen . . . do.	5.00	4.50
Carbon . . . do.	71.46	69.99
Nitrogen . . . do.	1.32	1.28
Oxygen . . . do.	8.38	7.84
Heat value . . . B.t.u.	12,200	11,878

KENTUCKY NO. 2B.

Coke breeze from Earlington, Hopkins County, on the Louisville & Nashville Railroad, was designated Kentucky No. 2B, and one part of the sample was used in briquetting test 102, and another part mixed with Illinois No. 20 coal was used in briquetting tests 103 and 104. No chemical analyses were made for briquetting test 102. Briquetting tests 103 and 104 are included under the discussion of Illinois No. 20.

In test 102 the size of the coal as used was as follows: Over one-fourth inch, 10.25 per cent; one-tenth inch to one-fourth inch, 31 per cent; one-twentieth inch to one-tenth inch, 18.75 per cent; one-fortieth inch to one-twentieth inch, 18.55 per cent; through one-fortieth inch, 21.45 per cent. The English machine was used, the temperature of the briquets being 179.6° F. A coal-tar pitch and a water gas pitch binder were used, the proportions being 6 and 7 per cent. Twenty-five tons of fuel was briquetted.

The briquets were soft when hot, but on cooling were hard enough to stand handling. Various mixtures made no apparent difference. All briquets showed coarse structure and were easily fractured. Attempted boiler tests were discontinued, owing to difficulty in maintaining steam. Broken briquets burned better than whole ones. For pitch analyses, see laboratory Nos. 2729, 2735, and 2748. All of these briquets were sent to the Big Four Railway Co. for preliminary locomotive test. The results were unsatisfactory.

MARYLAND NO. 2.

Bituminous run-of-mine coal from the Big Vein, or Pittsburgh bed, one-half mile west of Lord, Allegany County, on the Baltimore & Ohio Railroad, was designated Maryland No. 2 and a part of the sample was used in briquetting tests 191, 192, 193, and 231.

In tests 191, 192, 193, and 231 the size of coal used was as follows: Over one-fourth inch, 2.2 per cent; one-tenth inch to one-fourth inch, 9.8 per cent; one-twentieth inch to one-tenth inch, 26 per cent; one-fortieth inch to one-twentieth inch, 28.2 per cent; through one-fortieth inch, 33.8 per cent. Various proportions of binder (5, 6, and 7 per cent) made equally good briquets on the English machine. The briquets had smooth, firm surfaces, characteristic glossy fracture, and sharp edges. Renfrow briquets were satisfactory, but owing to faulty operation in the heater the best results were not obtained. Excellent briquets can be made from this coal with 5 per cent of binder.

Briquetting tests.

	Test No.			
	191.	192.	193.	231.
Details of manufacture:				
Machine used	English.	English.	English.	Renfrow No.1.
Briquetting temperature °F.	185	185	185	131
Binder—				
Kind	W. G. P.	W. G. P.	W. G. P.	W. G. P.
Laboratory No.	4543	4543	4543	4806
Amount per cent.	5	6	7	8
Weight of—				
Fuel briquetted pounds.	4,000	4,000	4,000	17,000
Briquets, average do.	3.35	3.32	3.47	0.453
Drop test (1-inch screen):				
Held per cent.	75.9	79.3	82.5	24.0
Passed do.	21.1	20.7	17.5	76.0
Tumbler test (1-inch screen):				
Held do.	74.0	78.2	80.2	66.5
Passed (fines) do.	26.0	21.8	19.8	33.5
Fines through 10-mesh sieve do.	75.6	77.8	63.0	85.0
Weathering test:				
Time exposed days.	5	5	5	....
Condition	A	A	A	....
Absorption test:				
Time immersed days.	19	19	19	19
Water absorbed per cent.	11.9	15.6	10.5	14.4
Average for first 4 days do.	1.45	1.85	1.30	2.25
Specific gravity (apparent	1.118	1.076	1.143	1.071

Chemical analyses of coal and briquets.

	Raw fuel.	Tests 191, 192, and 193.	Test 231.
Laboratory No.	4335	4415	4767
Proximate:			
Moisture ... per cent..	2.35	6.83	4.21
Volatile matter ... do....	16.97	19.71	20.71
Fixed carbon ... do....	72.53	66.01	68.54
Ash ... do....	8.15	7.45	6.54
Sulphur ... do....	.76	.86	.94
Ultimate:			
Hydrogen ... do....	4.44	4.33	4.61
Carbon ... do....	82.18	81.52	83.26
Nitrogen ... do....	1.48	1.79	1.64
Oxygen ... do....	2.77	3.44	2.68

Extraction analyses.

	Pitches.		Fuel.	Briquets.	
			Maryland No. 2.	Tests 191, 192, and 193.	Test 231.
Laboratory No.	4543	4806	4335	4415	4767
Air-drying loss ... per cent..	....	....	1.80	6.00	3.40
Extracted by CS_2 (as received) ... do....	99.66	96.90	.20	5.42	7.61
Pitch in briquet by analysis ... do....	....	....	....	5.25	7.69
Heat value ... B. t. u..	16,969	16,864	14,173	13,581	14,098

MISSOURI NO. 1.

A sample of bituminous run-of-mine coal from New Home, Bates County, on the Frisco system, was designated Missouri No. 1, and a part of the sample was subjected to briquetting tests on the English machine at the St. Louis plant.

At the time this coal was tested only the hard pitch was available. Two and a half tons of this coal that had previously been washed was briquetted with 11.5 per cent of pitch A. The briquets were black in color and sufficiently hard to stand rough handling, but on account of the pitch setting too quickly they were insufficiently pressed and were granular and porous. This coal will, however, briquet very readily, and with softer pitches, as pitch D and pitch H, will make a good briquet with about 6 to 7 per cent of binder.

The briquets were tested under the boiler.

Chemical analyses of coal and briquets.

	Car sample.	Briquets.
Laboratory No.	1126	1206
Proximate:		
Air-drying loss ... per cent..	5.00	2.90
Moisture ... do....	8.33	6.38
Volatile matter ... do....	33.58	37.60
Fixed carbon ... do....	38.73	41.85
Ash ... do....	19.36	14.17
Sulphur ... do....	5.25	4.56
Ultimate:		
Hydrogen ... do....	4.41	4.63
Carbon ... do....	62.18	68.52
Nitrogen ... do....	1.03	1.16
Oxygen ... do....	5.53	5.69
Heat value ... B. t. u..	10,586	11,867

MISSOURI NO. 10.

Bituminous screenings, through a ¾-inch shaking screen, from the Bevier bed at Bevier, Macon County, on the Chicago, Burlington & Quincy Railroad, were designated Missouri No. 10, and a part of the sample was used in briquetting tests 178, 179, 241, 245, and 246.

In tests 178, 179, 241, 245, and 246 the size of coal used was as follows: Over one-fourth inch, 3 per cent; one-tenth inch to one-fourth inch, 10.2 per cent; one-twentieth inch to one-tenth inch, 17.2 per cent; one-fortieth inch to one-twentieth inch, 21.2 per cent; through one-fortieth inch, 48.4 per cent. Equally satisfactory briquets were made with 7 and 8 per cent of binder on the English machine, and 8 and 9 per cent on the Renfrow machine. The large amount of clay present made the briquets soft when warm, but very hard when cold, if the fuel was worked with high moisture content. Tests 178 and 179 were made of coal from the same car and under greater pressure than in other tests. The briquets from the two tests were harder, more cohesive, and made less slack in handling. All the briquets had rough surfaces and broke with ragged fracture. They were of a dull-gray color, owing to the amount of clay present.

Briquetting tests.

	Test No.				
	178.	179.	241.	245.	246.
Details of manufacture:					
Machine used	Renfrow No. 1.	English.	Renfrow No. 1.	Renfrow No. 1.	English.
Briquetting temperature °F.	176	185	149	149	149
Binder—					
Kind	W. G. P.	W. G. P.	W. G. P.	W. G. P.	W. G. P.
Laboratory No.	4543	4543	4806	4879	4879
Amount per cent	8	7	9	8.5	8
Weight of—					
Fuel briquetted, pounds	42,000	5,000	66,000	176,000	10,000
Briquets, average, pounds	0.476	4.43	0.481	0.523	3.91
Drop test (1-inch screen):					
Held per cent	80.5	63.3	73.0	58.0	64.4
Passed do	19.5	36.7	27.0	42.0	35.6
Tumbler test (1-inch screen):					
Held per cent	94.0	90.9	91.5	87.0	64.2
Passed (fines) do	6.0	9.1	8.5	13.0	35.8
Fines through 10-mesh sieve per cent	99.0	80.9	95.0	90.3	50.0
Weathering test:					
Time exposed days	19	19	....	....	....
Condition	B	C	....	....	....
Absorption test:					
Time immersed days	19	19	13	13	13
Water absorbed, per cent	14.5	7.6	9.0	13.1	6.6
Average for first 5 days, per cent	1.94	....	1.54	2.24	1.12
Average for first 2 days, per cent	....	2.2	....	....	....
Specific gravity (apparent)	1.172	1.238	1.207	1.108	1.248

Chemical analyses of coal and briquets.

	Raw fuel.	Raw fuel.	Test 178.	Test 179.	Test 241.	Test 245.	Test 246.
Laboratory No	4257	4803	4515	4362	4898	4876	4908
Proximate:							
Moisture ..... per cent	15.23	14.10	11.03	4.51	8.91	7.79	7.75
Volatile matter ..... do	26.32	27.64	32.24	35.53	31.81	31.46	32.48
Fixed carbon ..... do	37.95	37.02	38.67	41.37	38.17	39.87	40.95
Ash ..... do	20.50	21.24	18.06	18.59	21.11	20.88	18.82
Sulphur ..... do	3.69	4.56	3.72	3.90	4.49	4.66	4.53
Ultimate:							
Hydrogen ..... do	3.93	3.88	....	4.34	4.16	4.12	4.24
Carbon ..... do	58.28	56.06	....	64.29	60.16	60.63	62.77
Nitrogen ..... do	.99	1.01	....	.91	.84	.84	.91
Oxygen ..... do	8.27	9.01	....	6.91	6.73	6.71	6.76

Extraction analyses.

	Fuel.		Briquets.		
			Test 178.	Test 179.	Test 241.
Laboratory No	4257	4803	4515	4362	4898
Air-drying loss ..... per cent	13.70	10.30	9.40	1.30	....
Extracted by CS_2 (as received) ..... do	0.47	0.47	7.44	7.54	8.44
Pitch in briquet by analysis ..... do	....	....	7.03	7.13	8.27
Heat value ..... B. t. u.	9,099	9,081	....	11,128	10,082

	Pitch.			Briquets.	
				Test 245.	Test 246.
Laboratory No	4543	4806	4879	4876	4908
Extracted by CS_2 (as received) ..... per cent	99.66	96.90	94.50	8.68	7.63
Pitch in briquet by analysis ..... do	....	....	....	8.73	7.62
Heat value ..... B. t. u.	16,969	16,864	16,805	10,262	10,580

MONTANA NO. 1.

A sample of black lignite (or subbituminous coal No. 4, nut, washed) from Red Lodge, Carbon County, on the Northern Pacific Railroad was designated Montana No. 1 and a part of the sample was subjected to briquetting tests on the English machine at the St. Louis plant.

This coal was dried slightly before briquetting. It was tested with 16 per cent of pitch A. The full limit of pressure that could be obtained on the English machine was used, and although the briquets were well pressed, they were somewhat porous and rough on the surface. They were black, but not glossy. They stood rough handling, and weighed on the average 6.30 pounds each.

The coal was briquetted with 7 per cent of pitch B, the highest pressure obtainable being used. As received from the press, the briquets were somewhat plastic, but on cooling proved to be brittle. They weighed on an average 7 pounds each.

Inability to control the moisture content of the mixture in the English machine was probably the cause of the poor results obtained in this test, but as the mixture had to be heated in this machine by the introduction of direct steam into the mass it was impossible to prevent the condensed steam from adding to the moisture content of the mixture, and as this class of fuels has an affinity for water the moisture was readily absorbed into the coal substance and resulted in a weak briquet.

Chemical analysis.

	Car sample.		Car sample.
Laboratory No.	1298	Ultimate:	
Proximate:		Hydrogen per cent	4.65
Air-drying loss per cent	2.20	Carbon do	66.42
Moisture do	11.05	Nitrogen do	1.50
Volatile matter do	35.90	Oxygen do	13.16
Fixed carbon do	42.08	Heat value B. t. u.	10,539
Ash do	10.97		
Sulphur do	1.73		

NEW MEXICO NO. 1.

A sample of run-of-mine subbituminous coal from a bed 3 miles north of Gallup, McKinley County, on the Santa Fe Railroad, was designated New Mexico No. 1 and a part of the sample was subjected to briquetting tests on the English and American machines at the St. Louis plant.

This coal was first briquetted with 12 per cent of pitch A, but the briquets were unsatisfactory in every way. Five and one-half tons of this coal was briquetted with 15.8 per cent pitch X, and the briquets were seemingly good in every way and could be handled easily without crumbling. On cooling, however, they began to crumble, and did not weather well. In burning they showed a decided tendency to disintegrate.

This coal was tested on the English machine with 8 per cent of pitch D. The briquets were rather crumbly and earthy, and on cooling were covered with a white efflorescent substance. They did not contain a sufficient quantity of pitch. They weighed on an average 6.83 pounds each and had a specific gravity of 1.13. Their crushing strength was 7,120 pounds, or 248 pounds to the square inch.

As 8 per cent of pitch D did not give any excess of binder, and as the briquets were not satisfactory, another ton of this coal was tested with 10 per cent of pitch D. Although the briquets fresh from the machine were somewhat stronger than those with 8 per cent of pitch D, on standing and becoming thoroughly cool they became so like those made with 8 per cent of pitch D that the two could not be distinguished from each other. This indicated that a satisfactory briquet could not be made from this coal with this pitch, even by greatly increasing the percentage. In making these briquets the English machine was run under ideal conditions; the pressure was constant, and the coal was sufficiently dry and not too fine and could be briquetted at a moderate temperature. The briquets showed a little more of the white efflorescent substance with 10 per cent than with the 8 per cent of pitch D, although they were rather glossy. The average weight of the briquets was 6.42 pounds each and their specific gravity was 1.02. Their crushing strength was 5,900 pounds, or 206 pounds per square inch, as compared with 248 pounds per square inch for those made with 8 per cent of pitch D. The eggettes were glossy on the surface but had a dull fracture and were not tenacious. They showed a tendency to disintegrate in burning.

The most satisfactory test was with pitch H, 1 ton of coal being briquetted with 8 per cent of pitch. The briquets were hard, strong, and clean—much better in every way than any briquets of this coal made with pitch D. They weighed on the average 6.25 pounds each and their specific gravity was 1.06. Their crushing strength was 13,050 pounds, or 454 pounds to the square inch, being nearly twice the strength of those made with 8 per cent of pitch D.

Chemical analysis.

	Car sample.		Car sample.
Laboratory No.	1278	Ultimate:	
Proximate:		Hydrogen per cent	5.07
Air-drying loss per cent	1.60	Carbon do	72.18
Moisture do	12.29	Nitrogen do	1.17
Volatile matter do	34.58	Oxygen do	12.89
Fixed carbon do	46.11	Heat value B. t. u.	11,252
Ash do	6.99		
Sulphur do	.63		

NEW MEXICO NO. 2.

A sample of subbituminous slack from 1½ miles east of Gallup, McKinley County, on the Santa Fe system, was designated New Mexico No. 2, and a part of the sample was subjected to briquetting tests on both the English and American machines at the St. Louis plant.

This subbituminous coal is almost identical with New Mexico No. 1. It was tested with 9.3, 10.5, and 12 per cent of pitch X, but in every case the briquets were crumbly and no positive results could be obtained.

The coal was next tested with pitch D as a binder, 1 ton of the coal being briquetted with 7 per cent of pitch D. The briquets were crumbly, gray in color, and had an earthy fracture. They were neither hard nor strong and were porous, although the limit of pressure was applied. There did not seem to be any difference in the briquet, whether made with a low or a high pressure. A large amount of grayish efflorescent substance appeared on the briquets almost immediately. The briquets weighed on an average 7 pounds each. The eggettes made from this mixture, although not so porous, had the same earthy appearance, fracture, and gray color.

Another ton of this coal was briquetted with 9 per cent of pitch D; an excess of pitch, due to its partial volatilization, was indicated by the bluish color on the surfaces. On account of an excess of steam, the briquets were rather soft as received from the machine, and owing to the excess of pitch many of them stuck together. Although they were better than those made with 7 per cent of pitch D, they would not have served as commercial briquets. They weighed on an average 7.12 pounds each. The coal was very dirty and contained considerable clay, and the same difficulties were experienced in briquetting it with pitch as were encountered with the Indian Territory No. 6 coal and pitch. From the work done on this sample it has been definitely proved that such dirty lignites can not well be briquetted with any commercial percentage of pitch as a binder, unless perhaps it is a pitch made from petroleum, as pitch H.

Five tons of this coal was briquetted on the American machine by using 10.25 per cent of the Hoffman patent binder, consisting of petroleum, rosin, and quicklime. The briquets were not tough, but held together rather satisfactorily when burned under the boiler. A steaming test was made of these eggettes.

Chemical analyses of coal and briquets.

	Car sample.	Briquets.
Laboratory No.	1307	1263
Proximate:		
Air-drying loss ... per cent	2.90	1.00
Moisture ... do	10.79	6.75
Volatile matter ... do	33.82	37.56
Fixed carbon ... do	36.73	39.08
Ash ... do	18.66	16.61
Sulphur ... do	1.26	1.61
Ultimate:		
Hydrogen ... do	4.51	4.92
Carbon ... do	61.73	66.73
Nitrogen ... do	1.06	.87
Oxygen ... do	10.37	7.95
Heat value ... B. t. u.	9,907	11,412

NORTH DAKOTA NO. 1.

A sample of lignite from Lehigh, Stark County, on the Northern Pacific Railroad, was designated North Dakota No. 1, and a part of the sample was subjected to briquetting tests on the English and American machines at the St. Louis plant.

This lignite is tough and woody, and does not distintegrate readily. In the first test the lignite was not previously dried and was mixed with 10 per cent of pitch A. Although the highest possible pressure was used, the briquets were porous and had the appearance of an incoherent mass of chips. With 12 per cent of pitch A the briquets were still porous and noncoherent, and on standing for some time exposed to the weather the grains and fragments of lignite began to slack off. Between the fragments of lignite there was an excess of pitch, but it did not seem to have any adhesion for the fragments. As the briquets were cooling, the contained steam acted upon the lignites, giving them the appearance of lumps of soft, brown loam surrounded by pitch.

The next test was made with dry material, the lignite having been previously ground to about 4-mesh fineness. One ton of this dry, fine material was mixed with 12 per cent of pitch A and run through the English machine, only one side of the disintegrator being used. There was no excess of steam and the full pressure was used, but the briquets were open. With both sides of the disintegrator in use there was a slight improvement in the briquets, but they were all porous and incoherent, and on exposure to the weather began to disintegrate. There was seemingly an excess of pitch between the flakes similar to that observed in the first ton tested. The same mixtures were tested on the American machine, and the eggettes when first received had a polished, lustrous appearance, but became rough immediately and had almost no coherence. The lignite was tested further by increasing the percentage of pitch, allowing the mixtures to remain longer in the pug mill, and increasing the pressure to the limit that could be attained on the English machine, but no briquets were obtained that had any coherence, and the results were all unsatisfactory.

The poor results obtained were probably due to the absorption of moisture by the lignite from the condensed steam used to heat the mixture, as it was impossible with the English machine to prevent an excess of moisture being present in the mixture. The excess of moisture was injurious only to fuels like lignite, which readily absorb considerable moisture and are weakened by the action of the moisture.

Chemical analysis.

	Car sample.		Car sample.
Laboratory No.	1279	Ultimate:	
Proximate:		Hydrogen ... per cent	4.15
Air-drying loss ... per cent	23.60	Carbon ... do	62.26
Moisture ... do	35.38	Nitrogen ... do	.84
Volatile matter ... do	29.59	Oxygen ... do	15.88
Fixed carbon ... do	25.68	Heat value ... B. t. u.	6,923
Ash ... do	9.35		
Sulphur ... do	1.55		

NORTH DAKOTA—PITTSBURGH NO. 11.

A car of run-of-mine lignite from the Scranton mine, Scranton, Bowman County, N. Dak., was designated Pittsburgh No. 11. This lignite had a dark-brown, almost black color, but became somewhat lighter colored after drying.

Briquetting tests 312, 317, 318, 319, and 322 were made of the raw lignite at Pittsburgh on the German press, without binder. House-heating boiler tests H86 and H87 were made of briquets from briquetting test 322.

Test 312 of material dried till it held 10.6 per cent moisture furnished some fairly strong briquets during the latter half of the run when conditions had become constant. The shape of these briquets was good, their surfaces were smooth, and their edges were sharp. They could be handled without too much breakage. The best briquets were made by running the machine at moderate speed—about 60 revolutions per minute.

Test 317, in which the material was dried until it contained 11 per cent moisture and the pressure used was heavier than in test 312, failed to produce satisfactory briquets. Those formed were too weak to stand handling and crumbled to pieces soon after leaving the mold. The chemical analysis reported was made of the broken briquets.

Test 318, in which the material contained 11.7 per cent moisture and the pressure was the same as in test 317, furnished some fair briquets during the latter part of the run, but they were not strong enough to stand handling. As in test 317, pieces of briquets were analyzed.

Test 319, in which the material contained 15 per cent moisture, produced excellent briquets; they had smooth surfaces sharp edges and were strong enough to bear handling.

The conditions during test 322 differed from those during test 319 only in the moisture content of the material. The briquets were strong and well formed, with smooth, polished surfaces.

Plates XVI to XXI show how briquets from tests 312, 319, and 322 withstood exposure to the weather.

This lignite was made into good briquets without the use of a binder. Satisfactory briquets can be made by drying the ground lignite until it contains 11 per cent moisture, and better briquets can be made if the moisture content is about 15 per cent. The indications are that material containing more than 15 per cent moisture can be worked on this press and will probably furnish briquets stronger than any other lignites mentioned in this report. Unfortunately, the control of the drier at the Pittsburgh plant did not permit the material, if dried at all, to contain more than 15 per cent moisture. This defect can be remedied, however, by changing the proportions or the speed of the drier.

Data relating to the test made with this lignite are summarized in the table following:

Briquetting tests.

	Test No.				
	312.	317.	318.	319.	322.
Size as shipped	r. o. m.	r. o. m.	r. o. m.	r. o. m.	r. o. m.
Size as used:					
Over ¼ inch, per cent	2.00	3.00	1.00	3.00	1.50
1/10 to ¼ inch, per cent	21.00	29.50	17.50	32.00	29.00
1/20 to 1/10 inch, per cent	28.00	25.00	32.50	29.50	29.00
1/40 to 1/20 inch, per cent	26.00	16.50	22.00	16.50	20.00
Through 1/40-inch, per cent	23.00	26.00	27.00	19.00	20.50
Details of manufacture:					
Machine used	German.	German.	German.	German.	German.
Briquetting temperature, ° F	103	98	101	99	102
Binder used	None.	None.	None.	None.	None.
Tangent of die angle	6/89	7/89	7/89	7/89	7/89
Steam pressure on drier, pounds	10	10	5	4	4
Weight of—					
Fuel briquetted, pounds	4,383	None.[a]	2,000	4,000	6,300
Briquets, average, pounds	1.00		1.00	1.03	1.07
Moisture in briquet mixture, per cent	10.60	11.06	11.73	14.96	12.60
Drop test (1-inch screen):					
Held, per cent	42			44	34
Passed, per cent	58			56	66
Tumbler test (1-inch screen):					
Held, per cent	36			43	37
Passed, per cent	64			57	63
Fines through 10-mesh sieve, per cent	65			56	59
Weather test:					
Time exposed when examined, days	66			66	66
Condition when examined	E			E	D

[a] The few briquets made fell to pieces when handled.

The table following shows the changes in composition of this lignite during transportation from the mine to the plant, a period of 38 days, and during storage at the plant until used for the last briquetting test, a period of 50 days. The fourth column gives an average of five proximate analyses made on different dates, and analyses of the briquets are also given.

Chemical analyses.

	Mine sample.	Car sample.	Sample as used on last test.	Average of 5 samples.
Date taken	Mar. 20	Apr. 23	June 12	
Laboratory No.	7499	7677	7942	
Proximate:				
Moisture, per cent	41.43	38.81	32.30	32.68
Volatile matter, do	23.86	25.48	18.81	26.24
Fixed carbon, do	28.45	27.29	40.71	33.45
Ash, do	6.26	8.42	8.18	7.62
Sulphur, do	.74	.97	.85	.93
Ultimate:				
Hydrogen, do		4.54		
Carbon, do		61.20		
Nitrogen, do		.82		
Oxygen, do		18.09		
Heat value, B. t. u.	6,241	6,347	7,160	7,243

Proximate analyses of briquets.

	Briquet 312.	Briquet 317.	Briquet 318.	Briquet 319.	Briquet 322.
Laboratory No	7807	7886	7893	7901	7944
Moisture per cent	10.76	10.70	12.09	12.48	11.93
Volatile matter do	38.97	38.95	38.11	38.92	36.87
Fixed carbon do	40.94	40.69	39.68	39.47	41.37
Ash do	9.33	9.66	10.12	9.13	9.83
Sulphur do	1.22	1.20	1.27	1.20	1.21
Heat value B. t. u.	9,434	9,470	9,189	9,184	9,445

Extraction analyses.

	Fuel.				Briquets.	
					Test 312.	Test 322.
Laboratory No.	7499	7677	7942	....	7807	7944
Air-drying loss per cent	36.00	27.50	22.70	20.70	....	....
Extracted by CS_2 (moisture free) do	....	....	1.71	1.76	1.67	1.68

NORTH DAKOTA—PITTSBURGH NO. 13.

The sample designated Pittsburgh No. 13 consisted of 1 car of run-of-mine lignite from the Lehigh mine, Stark County, N. Dak. It was used in making gas-producer test 184 and briquetting tests 294, 298, 299, 300, 301, 302, 303, 304, 305, 306, and 307 with the German press.

The ground and dried lignite used in test 294 contained 11 per cent moisture. It made well-formed briquets that had rather brittle edges and cracked sides. They were strong enough to endure careful handling and were the strongest lot made from this fuel.

In tests 298, 299, 300, 301, 302, 303, and 304 the moisture content and the pressure were varied in an endeavor to get the best conditions, but the few briquets made were too weak and were not kept.

In test 305 the material contained about 15 per cent moisture. Some of the briquets were strong enough to endure careful handling, but they were softer than those from test 294 and crumbled more easily. Seemingly the material was too coarse and contained too much moisture. The briquets were, however, a great improvement over those from tests 298 to 304.

Test 306 produced some fairly good briquets, there being little choice between the lot and those from test 305. Seemingly the moisture content of the dried material was too high. The briquets crumbled easily and when struck gave a dull sound instead of the sharp, metallic ring of good briquets. The briquets from tests 305 and 306 were mixed in storage, and the cohesion tests were made from a mixed sample.

The briquets made in test 307 had better forms than those from any other test of this fuel, but were not so strong as those from tests 294, 305, or 306.

This series of tests has demonstrated that this lignite can be made into briquets, but further tests are desirable to determine the best conditions. Fine grinding is a requisite. About 10 to 12 per cent moisture in the material seems desirable and a heavy pressure is necessary. The proportion of natural binder in the lignite being rather low, briquets made without adding artificial binder are likely to be weak. Probably the use of a small proportion, perhaps 2 to 4 per cent, of artificial binder and a different type of press would give better briquets.

Briquetting tests.

	Test No.				
	294.	298.	299.	300.	301.
Size as shipped	R. o. m.	R. o. m.	R. o. m.	R. o. m.	R. o. m.
Size as used:					
Over ¼ inch...per cent	0.0	1.0	0.0	0.0	0.5
1/10 to ¼ inch...do	27.7	21.0	20.0	20.0	12.0
1/20 to 1/10 inch...do	40.0	31.5	36.0	36.0	28.5
1/40 to 1/20 inch...do	22.3	25.5	25.0	25.0	27.0
Through 1/40 inch...do	10.0	21.0	19.0	19.0	32.0
Details of manufacture:					
Machine used	German.	German.	German.	German.	German.
Briquetting temperature...° F	90	75	75	75	68
Binder used	None.	None.	None.	None.	None.
Tangent of die angle	5.5/89	6/89	6/89	4/89	4/89
Steam pressure on drier...pounds	20	20	20	20	15
Weight of—					
Fuel briquetted...do	2,840	None.	None.[a]	None.[a]	None.[a]
Briquets, average...do	0.775	....	....	....	....
Moisture in briquet mixture...per cent	11.13	9.19	9.88	9.88	9.19
Drop test (1-inch screen):					
Held...do	25	....	....	....	....
Passed...do	75	....	....	....	....
Tumbler test (1-inch screen):					
Held...do	30	....	....	....	....
Passed...do	70	....	....	....	....
Fines through 10-mesh sieve...do	67	....	....	....	....

	Test No.					
	302.	303.	304.	305.	306.	307.
Size as shipped	R. o. m.	R. o. m.	R. o. m.	R. o. m.	R. o. m.	R. o. m.
Size as used:						
Over ¼ inch...per cent	0.5	0.5	0.5	2.0	0.8	0.8
1/10 to ¼ inch...do	18.0	20.0	21.0	22.5	21.5	21.5
1/20 to 1/10 inch...do	24.0	34.5	31.5	30.5	32.2	32.2
1/40 to 1/20 inch...do	26.0	25.5	24.5	21.5	22.5	22.5
Through 1/40 inch...do	31.5	19.5	22.5	23.5	23.0	23.0
Details of manufacture:						
Machine used	German.	German.	German.	German.	German.	German.
Briquetting temperature...°F	78	74	88	81	85	102
Binder used	None.	None.	None.	None.	None.	None.
Tangent of die angle	4/89	5/89	6/89	6/89	6/89	6/89
Steam pressure on drier...pounds	10	10	10	8	12	16
Weight of—						
Fuel briquetted...do	[b] 500	[b] 700	[b] 1,950	1,880	2,138	700
Briquet, average...do	....	....	0.9	0.77	0.77	0.82
Moisture in briquet mixture...per cent	9.81	11.02	11.56	14.80	12.12	9.29
Drop test (1-inch screen):						
Held...do	....	....	....	16.00	16.00	5.00
Passed...do	....	....	....	84.00	84.00	95.00
Tumbler test (1-inch screen):						
Held...do	....	....	....	17.00	17.00	7.00
Passed...do	....	....	....	83.00	83.00	93.00
Fines through 10-mesh sieve...do	....	....	....	60.00	60.00	60.00

[a] The few briquets made were too weak to handle.
[b] Briquets were scrapped, as they were too weak to handle.

The table following shows the changes in composition of this fuel during transportation from the mine to the plant, a period of 12 days, and during storage at the plant until used for the last briquetting test, a period of 30 days. The fourth column is an average of eight proximate analyses of samples used on different dates. Analyses of the briquets are also given.

Chemical analyses of coal.

	Mine sample.	Car sample.	Sample as used on last test.	Average of 8 samples.
Date taken	Mar. 29	Apr. 10	May 10	....
Laboratory No.	7537	7553	7752	....
Proximate:				
Air-drying loss ... per cent	37.80	34.30	28.90	28.68
Moisture ... do	42.04	40.23	38.95	38.08
Volatile matter ... do	23.40	24.89	24.44	24.86
Fixed carbon ... do	27.67	28.03	29.38	29.74
Ash ... do	6.89	6.85	7.23	7.32
Sulphur ... do	.68	.62	.91	.90
Ultimate:				
Hydrogen ... do	....	4.28	....	....
Carbon ... do	....	62.66	....	....
Nitrogen ... do	....	.70	....	....
Oxygen ... do	....	19.86	....	....
Extract by CS_2 (moisture free) ... do	....	....	1.16	....
Heat value ... B. t. u.	6,079	6,246	6,327	6,579

Chemical analyses of briquets.

	Test No.							
	294	301	302	303	304	305	306	307
Laboratory No.	7611	7702	7703	7719	7723	7726	7755	7751
Proximate:								
Air-drying loss ... per cent	0.60	......	......	......	......	......	......	......
Moisture ... do	8.56	8.30	10.87	10.26	10.18	12.10	11.41	10.29
Volatile matter ... do	37.51	37.00	36.83	38.79	37.82	35.00	36.52	37.14
Fixed carbon ... do	41.23	42.80	42.71	42.35	43.00	44.10	42.55	43.93
Ash ... do	12.70	11.90	9.59	8.60	9.00	8.80	9.52	8.64
Sulphur ... do	2.24	1.90	1.58	1.12	1.21	1.35	1.40	1.02
Extract by CS_2 (moisture free) . do	1.72	1.66	1.85	1.01	......	1.51	......	1.19
Heat value ... B. t. u.	9,191	9,410	9,504	9,691	9,684	9,000	9,490	9,698

NORTH DAKOTA—PITTSBURGH NO. 15.

A sample consisting of one car of 3-inch lump lignite from the McClure mine, Vanderwalker, Ward County, N. Dak., was designated Pittsburgh No. 15.

Briquetting tests 324, 325, 326, and 330 were made of it with the German press without binder. No gas-producer or steaming tests were made.

Dried lignite containing 7.4 per cent moisture was used for tests 324 and 325. In test 324 a set of dies, used in test 323, gave the heaviest pressure the machine would stand. The material stalled the machine, the end of a stamp broke, and no briquets were made.

Another set of dies giving less pressure was used for test 325 on the same lot of material. The material would not work satisfactorily, however, with this set of dies, and after several attempts the test was stopped and the rest of the lignite in the hopper was thrown away.

The next lot of ground lignite, dried to contain 10.8 per cent moisture, was used for test 326. No briquets were made and the material came out of the press in a loose form. The lignite evidently lacked binding properties, a defect that was confirmed by extraction tests made later. Another test (330) was made of a lot of material dried to contain 11.6 per cent moisture, but no briquets were formed. Similar results were obtained in tests 326 and 330. No further test could be made on this lignite at the time.

The lignite seemingly does not contain enough binding material to form briquets on the German press. Without doubt, it can be successfully briquetted by adding a binder and using a press made to work with a binder. It is desirable to make further tests of this lignite, first on the laboratory hand press and afterwards on the English machine belonging to the Bureau of Mines.

Briquetting tests.

	Test No.			
	324.	325.	326.	330.
Size as shipped	3-inch lump.	3-inch lump.	3-inch lump.	3-inch lump.
Size as used:				
Over $\frac{1}{4}$ inch ... per cent	1.5	1.5	2.0	1.0
$\frac{1}{10}$ to $\frac{1}{4}$ inch ... do	28.0	28.0	30.0	30.0
$\frac{1}{20}$ to $\frac{1}{10}$ inch ... do	30.0	30.0	29.5	28.0
$\frac{1}{40}$ to $\frac{1}{20}$ inch ... do	20.5	20.5	18.5	19.0
Through $\frac{1}{40}$ inch ... do	20.0	20.0	20.0	22.0
Details of manufacture:				
Machine used	German.	German.	German.	German.
Briquetting temperature ... °F	93	93	93.6	111
Binder used	None.	None.	None.	None.
Tangent of die angle	7/89	6/89	6/89	6/89
Steam pressure on drier ... pounds	5	5	4	3
Weight of—				
Fuel briquetted ... do	None.	None.	None.	None.
Moisture in briquet mixture ... per cent	7.40	7.40	10.80	11.60

The changes in composition of the fuel during transportation from the mine to the plant, a period of 44 days, and during storage at the plant for 73 days, are shown below. The figures in the fourth column represent an average of three analyses made on different dates.

Chemical analyses.

	Mine sample.	Car sample.	Sample as used on last test.	Average of 3 samples.
Date taken	Apr. 3	Apr. 17	June 29	....
Laboratory No.	7587	7631	8020	....
Proximate:				
Air-drying loss ... per cent	28.90	25.60	18.30	15.83
Moisture ... do	36.64	34.30	29.09	27.94
Volatile matter ... do	22.64	23.10	27.13	27.12
Fixed carbon ... do	30.74	29.93	34.88	34.99
Ash ... do	9.98	13.67	8.90	9.95
Sulphur ... do	.45	.52	.56	.54
Ultimate:				
Hydrogen ... do	....	3.76	....	....
Carbon ... do	....	56.01	....	....
Nitrogen ... do	....	.87	....	....
Oxygen ... do	....	17.76	....	....
Extract by CS_2 (moisture free) ... do	....	....	....	1.08
Heat value ... B. t. u.	6,394	6,284	7,385	7,364

PENNSYLVANIA NO. 3.

A sample of anthracite culm from near Scranton was designated Pennsylvania No. 3 and a part of the sample was subjected to briquetting tests on both the English and American machines at the St. Louis plant.

The first test was with 90 parts of the culm, 10 parts of a West Virginia coking coal, and 12½ per cent of hard pitch A. The mixture was run through the English machine, both sides of the disintegrator being used and the briquets being pressed to the limit of the machine. On account of the hardness of the anthracite coal it did not disintegrate to any great extent and the briquets resembled concrete. They were hard and tough, and even with the inferior pitch were of good quality. They weighed on an average 7.25 pounds each. During combustion they burned like lumps of anthracite coal, making little flame. On standing exposed to the weather, the briquets did not suffer to any extent except during hard rains, when their surfaces became pitted. Seemingly this pitting was due to the wearing away of the softer pitch from the harder fragments of anthracite.

The culm was next tested with the softer pitch B, by using 84 per cent of anthracite, 9 per cent of West Virginia coking coal, and 7 per cent of pitch B. For this test the coarsest and driest part of the culm was used. The combination made fair briquets, but they would have been improved if dry steam could have been used. The briquets weighed on an average 7.64 pounds each and had a specific gravity of 1.174, whereas the specific gravity of the raw culm was 1.52. The crushing strength of the briquets was only 4,500 pounds, or 156 pounds to the square inch. The eggettes of this mixture made on the American machine were harder and firmer than the corresponding briquets. They all burned like anthracite coal, except that in starting the fire they were more easily ignited.

Another ton of the anthracite culm, which had been kiln-dried, was briquetted with 7 per cent of pitch B, without the addition of any bituminous coal. If the steam introduced into the pug mill was wet the fresh briquets were almost too soft to handle. If, however, the steam was dry, they were firm and lustrous. Although the briquets were not so lustrous as those made with soft coal, they were clean, smooth, hard, and strong, and when dropped rang like a stone. The eggettes of this mixture made on the American machine were also very good, but no better than the briquets. The eggettes also burned like lump anthracite, with little flame or crumbling. In breaking the large briquets there was little waste. The briquets weighed on an average 7.4 pounds each, and had a specific gravity of 1.28, the specific gravity of the coal being 1.52. The crushing strength of the briquets was 17,100 pounds, or 596 pounds to the square inch, this test being made of briquets that had been exposed to the weather for over a month.

One ton of the anthracite culm also was tested with 7 per cent of pitch D as a binder, but, on account of lack of pressure, the briquets were porous and not so good as those that contained 7 per cent of pitch B. They stuck together while hot, indicating that 7 per cent of pitch D was sufficient and that an increase of pitch would not improve them. They weighed only 7.06 pounds each on an average.

A 5-ton lot of the anthracite culm was briquetted with 10 per cent of West Virginia coking coal and 11¼ per cent of the Hoffman patent binder, on the American machine. The eggettes were hard, smooth, and clean, with a somewhat polished surface, and stood considerable rough handling. The eggettes were tested by burning under a boiler, the fire box of which was fitted for a bituminous coal. Although made of 79¾ per cent of anthracite, they did not burn like anthracite, and their oil and rosin constituents gave a long flame to the fuel, and the boiler ran at 86 per cent of its rated capacity.

From the results of these tests it is apparent that anthracite culm can be satisfactorily briquetted either in combination with a coking coal or by using simply pitch as a binder, and that the briquets have most of the properties of lump anthracite.

Chemical analyses of coal and briquets.

	Car sample.	Briquets.
Laboratory No.	1245	1294
Proximate:		
Air-drying loss ... per cent	3. 40	0. 10
Moisture ... do	5. 41	3. 00
Volatile matter ... do	7. 02	27. 62
Fixed carbon ... do	71. 79	55. 00
Ash ... do	15. 78	14. 38
Sulphur ... do	. 74	1. 13
Ultimate:		
Hydrogen ... do	2. 64	4. 12
Carbon ... do	76. 81	74. 09
Nitrogen ... do	. 81	1. 08
Oxygen ... do	2. 27	4. 44
Heat value ... B. t. u.	12, 047	12, 893

PENNSYLVANIA NO. 15.

Semibituminous run-of-mine coal from the "Miller" or "B" bed at Wehrum, Indiana County, on the Pennsylvania Railroad, was designated Pennsylvania No. 15, and a part of the sample was used in briquetting tests 176 and 184, in mixture with Rhode Island No. 1. Steaming test 467 was made of the briquets from briquetting test 176. House-boiler test 47 was made of the briquets from briquetting test 184.

In test 176 the size of coal used was as follows: Over one-fourth inch, 2.2 per cent; one-tenth inch to one-fourth inch, 6 per cent; one-twentieth inch to one-tenth inch, 12 per cent; one-fortieth inch to one-twentieth inch, 19 per cent; through one-fortieth inch, 60.8 per cent. This test, with 7 per cent of binder, gave satisfactory briquets, which were tough and easily handled without breaking when warm, but were brittle when cold. They broke with characteristic smooth, glossy fracture, hard surface, and sharp edges.

In test 184 the size of coal used was as follows: Over one-fourth inch, 0.8 per cent; one-tenth inch to one-fourth inch, 7 per cent; one-twentieth inch to one-tenth inch, 15 per cent; one-fortieth inch to one-twentieth inch, 22.2 per cent; through one-fortieth inch, 55 per cent. Pennsylvania No. 15 was mixed with an equal quantity of Rhode Island No. 1 (run of mine) in this test. Excellent briquets were made with 6.25 per cent of binder on the Renfrow machine. Although the pitch used had a low melting point, the briquets handled well from the machine and piled without sticking. The outer surface was very hard and smooth, and broke without crumbling, giving a smooth fracture and sharp edges.

Briquetting tests.

	Test No.	
	176.	184.
Details of manufacture:		
Machine used	Renfrow No. 1.	Renfrow No. 1.
Temperature of briquets °F.	185	185
Binder—		
Kind	W. G. P.	W. G. P.
Laboratory No.	4543	4543
Amount per cent.	7	6.25
Weight of—		
Fuel briquetted pounds.	8,000	10,000
Briquets, average do.	0.420	0.5
Drop test (1-inch screen):		
Held per cent.	50.5	68.5
Passed do.	49.5	31.5
Tumbler test (1-inch screen):		
Held do.	70.5	93.0
Passed (fines) do.	29.5	7.0
Fines through 10-mesh sieve do.	85.0	91.4
Weathering test:		
Time exposed days.	53	11
Condition	A	A
Absorption test:		
Time immersed days.	19	16
Water absorbed per cent.	22.0	13.3
Average for first 4 days do.	4.05	....
Average for first 5 days do.	....	1.90
Specific gravity (apparent)	1.043	1.275

Chemical analyses of coal and briquets.

	Fuel.		Test 176.	Test 184.
	Pa. No. 15.	R. I. No. 1.		
Laboratory No.	4104	3216	....	4913
Proximate:				
Moisture ... per cent	2.57	2.41	3.90	0.74
Volatile matter ... do	18.09	4.92	23.35	15.96
Fixed carbon ... do	69.01	73.61	64.65	69.71
Ash ... do	10.33	19.06	8.10	13.59
Sulphur ... do	3.97	.07	3.11	2.61
Ultimate:				
Hydrogen ... do	4.25	.65	4.35	3.05
Carbon ... do	77.89	76.95	78.71	77.48
Nitrogen ... do	1.19	.17	1.09	.49
Oxygen ... do	2.00	2.63	4.18	2.65

Extraction analyses.

	Pitch.	Fuel.		Briquets.	
		Pa. No. 15.	R. I. No. 1.	Test 176.	Test 184.
Laboratory No.	4543	4104	3216	....	4913
Air-drying loss ... per cent	....	2.10	2.00	2.80	0.03
Extracted by CS_2 (as received) ... do	99.66	0.77	0.02	5.72	6.25
Pitch in briquet by analyses ... do	....	....	....	5.02	5.91
Heat value ... B. t. u.	16,969	13,712	10,996	13,702	12,793

PENNSYLVANIA NO. 16.

Semibituminous run-of-mine coal from the "D" bed at Hastings, Cambria County, on the Pennsylvania Railroad, was designated Pennsylvania No. 16 and a part of the sample was used in briquetting tests 172, 173, and 174. Steaming test 468 was made of equal parts of briquets from the three briquetting tests.

In tests 172, 173, and 174 the size of coal used was as follows: Over one-fourth inch, 2.2 per cent; one-tenth inch to one-fourth inch, 5.4 per cent; one-twentieth inch to one-tenth inch, 11.2 per cent; one-fortieth inch to one-twentieth inch, 21.4 per cent; through one-fortieth inch, 59.8 per cent. There was no difference in physical appearance between English briquets with 6 and those with 7 per cent of binder. All briquets were satisfactory, with smooth, very hard surface, characteristic glossy fracture, and sharp edges. Renfrow briquets broke without crumbling and were easily transported from the machine when warm.

Briquetting tests.

	Test No.		
	172.	173.	174.
Details of manufacture:			
Machine used	English.	English.	Renfrow No. 1.
Temperature of briquets °F	203	203	185
Binder—			
Kind	C. T. P.	C. T. P.	C. T. P.
Laboratory No	4319	4319	4319
Amount per cent	6	7	7
Weight of—			
Fuel briquetted pounds	3,500	3,500	5,000
Briquets, average do	3.66	3.69	0.428
Drop test (1-inch screen):			
Held per cent	76.1	80.4	44.5
Passed do	23.9	19.6	55.5
Tumbler test (1-inch screen):			
Held do	78.8	81.7	69.5
Passed (fines) do	21.2	18.3	30.5
Fines through 10-mesh sieve do	64.0	63.9	91.0
Weathering test:			
Time exposed days	54	50	54
Condition	A	A	B
Absorption test:			
Time immersed days	19	19	19
Water absorbed per cent	13.9	14.7	19.0
Average for first 4 days do	1.35	1.30	3.30
Specific gravity (apparent)	1.113	1.110	1.056

Chemical analyses of coal and briquets.

	Car sample.	Tests 172, 173, and 174.[a]
Laboratory No	4169	4253
Proximate:		
Moisture per cent	4.25	5.27
Volatile matter do	21.79	23.69
Fixed carbon do	66.09	62.69
Ash do	7.87	8.35
Sulphur do	1.59	1.68
Ultimate:		
Hydrogen do	4.44	4.36
Carbon do	79.29	79.42
Nitrogen do	1.34	1.29
Oxygen do	5.05	4.35

[a] Composite sample of briquets used in steaming test 468.

Extraction analyses.

	Pitch.	Fuel, Pa. No. 16.	Briquets, tests 172, 173, 174.
Laboratory No	4319	4169	4253
Air-drying loss per cent		3.90	4.50
Extracted by CS_2 (as received) do	66.25	.06	5.35
Pitch in briquet by analysis do			8.00
Heat value B. t. u.	16,139	13,513	13,487

PENNSYLVANIA NO. 18.

Semibituminous run-of-mine coal from a mine working the "Miller" bed, outcropping at Lloydell, Cambria County, on the Pennsylvania Railroad, was designated Pennsylvania No. 18, and a part of the sample was used in briquetting tests 196, 197, 200, 201, 202, 205, 232, 236, and 250; in mixture with Rhode Island No. 1 in briquetting test 243; and in mixture with miscellaneous No. 9 in briquetting tests 238, 239, 240, and 248. Four cars were shipped to the fuel-testing plant at St. Louis, and one car was shipped to the Pennsylvania Railroad locomotive testing plant at Altoona, Pa. Some of the briquets made from this coal were tested as locomotive fuel at Altoona, Pa., by the Pennsylvania lines.

In tests 196, 197, 200, 201, 202, 205, 232, 236, and 250 the size of coal as used was as follows: Over one-fourth inch, 1.4 per cent; one-tenth inch to one-fourth inch, 5 per cent; one-twentieth inch to one-tenth inch, 10.6 per cent; one-fortieth inch to one-twentieth inch, 24.8 per cent; through one-fortieth inch, 58.2 per cent. Excellent briquets were made on the English machine with 5, 6, and 7 per cent of binder; 8 per cent of binder gave good results on the Renfrow machine, but those with 6 and 7 per cent of binder were not satisfactory. This coal worked equally well with high and low moisture content, making briquets with hard surfaces that were easily handled and piled. The fracture was smooth, the particles of coal being so thoroughly cemented that the appearance was like a solid mass.

Briquetting tests.

	Test No.				
	196.	197.	200.	201.	202.
Details of manufacture:					
Machine used	English.	English.	English.	Renfrow No. 1.	Renfrow No. 1.
Temperature of briquets °F	158	140	185	149	149
Binder—					
Kind	W.G.P.	W.G.P.	W.G.P.	W.G.P.	W.G.P.
Laboratory No	4683	4683	4683	4683	4683
Amount per cent	6	7	5	6	7
Weight of—					
Fuel briquetted pounds	24,000	128,000	24,000	3,600	6,500
Briquets, average do	3.57	3.62	3.66	0.456	0.439
Drop test (1-inch screen):					
Held per cent	70.6	66.7	62.5	21.0	41.0
Passed do	29.4	33.3	37.5	79.0	59.0
Tumbler test (1-inch screen):					
Held do	66.0	66.1	72.2	51.0	71.0
Passed (fines) do	34.0	33.9	27.8	49.0	29.0
Fines through 10-mesh sieve do	76.0	59.5	77.6	89.7	89.2
Weathering test:					
Time exposed days	1	....	....	....	....
Condition	A	....	....	....	....
Absorption test:					
Time immersed days	19	19	13	13	13
Water absorbed per cent	14.9	12.0	11.5	17.4	16.0
Average for first 4 days do	1.85	1.55	2.10	3.12	2.88
Specific gravity (apparent)	1.129	1.161	1.131	1.088	1.106

Briquetting tests—Continued.

	Test No.			
	205.	232.	236.	250.
Details of manufacture:				
Machine used	Renfrow No. 1.	Renfrow No. 1.	English.	English.
Temperature of briquets °F.	158	167	158	157
Binder—				
Kind	W.G.P.	W.G.P.	W.G.P.	(*a*)
Laboratory No.	4806	4806	4806	4825
Amount per cent.	8	8	7	8
Weight of—				
Fuel briquetted pounds.	6,000	146,000	40,000	1.800
Briquets, average do.	0.407	0.469	3.62	3.91
Drop test (1-inch screen):				
Held per cent.	54.5	54.5	67.5	89.0
Passed do.	45.5	45.5	32.5	11.0
Tumbler test (1-inch screen):				
Held do.	85.0	89.5	61.8	91.9
Passed (fines) do.	15.0	10.5	38.2	8.1
Fines through 10-mesh sieve do.	89.7	90.3	53.4	46.2
Absorption test:				
Time immersed days.	13	13	13	13
Water absorbed per cent.	15.3	11.0	11.7	5.9
Average for first 4 days do.	2.33	1.83	2.13	0.95
Specific gravity (apparent)	1.102	1.164	1.156	1.240

a Wax tailings.

In test 238, with Pennsylvania No. 18, 75 per cent, and miscellaneous No. 9 (coke breeze), 25 per cent, satisfactory briquets were made with 8 per cent of binder; they were similar to briquets from Pennsylvania No. 18 alone. The surfaces were smooth and hard, the fractured surface being smooth, with sharp edges. The briquets could be handled easily while warm, and did not crush or stick together when piled warm.

In test 239, using equal parts of Pennsylvania No. 18 and miscellaneous No. 9, the briquets were softer when warm than those of test 238, but could be handled without breaking; they were very hard when cold and broke without crumbling; the fractured surface was rough but firm.

In test 240, with Pennsylvania No. 18, 25 per cent, and miscellaneous No. 9, 75 per cent, the briquets were very soft when warm and could not be handled without considerable breakage, but were hard when cold. The fractured surface was very rough, with edges that crumbled easily. This test showed the necessity of handling fuel mechanically until cold to prevent breakage.

In test 243 equal parts of Pennsylvania No. 18 and Rhode Island No. 1, both in run-of-mine form, were used. An effort was made to improve the burning qualities by increasing the melting point of the binder, but owing to the hardness of the pitch used and insufficient pressure the briquets were not satisfactory. They could not be handled when warm without many being broken, but when cold were brittle, producing considerable slack in handling. No physical tests were made.

In test 248, with Pennsylvania No. 18, 10 per cent, and miscellaneous No. 9, 90 per cent, the briquets had the characteristics of those from test 240. The breakage of warm briquets in falling from the machine and during handling with the coke fork was fully 50 per cent, showing the necessity of carefully handling the briquets with a belt conveyor until they are cool. The cold briquets were handled satisfactorily.

Briquetting tests.

	Test No.				
	238.	239.	240.	243.	248.
Size as used:					
Over $\frac{1}{4}$ inch..........per cent..	1.0	0.6	1.4	1.0	1.4
$\frac{1}{10}$ to $\frac{1}{4}$ inch..........do....	6.8	6.2	7.8	6.8	8.4
$\frac{1}{20}$ to $\frac{1}{10}$ inch..........do....	14.2	15.0	16.6	17.6	16.8
$\frac{1}{40}$ to $\frac{1}{20}$ inch..........do....	21.8	23.4	26.2	25.2	29.0
Under $\frac{1}{40}$ inch..........do....	56.2	54.8	48.0	49.4	44.4
Details of manufacture:					
Machine used..........	Renfrow No. 1.	Renfrow No. 1.	Renfrow No. 1.	Renfrow No. 1.	Renfrow No. 1.
Temperature of briquets..........°F..	167	167	167	185	158
Binder—					
Kind..........	W.G.P.	W.G.P.	W.G.P.	W.G.P.	W.G.P.
Laboratory No..........	4806	4806	4806	4625	4879
Amount..........per cent..	8.0	8.0	8.0	8.0	8.0
Weight of—					
Fuel briquetted..........pounds..	10,000	8,000	8,000	2,000	2,000
Briquets, average..........do....	0.485	0.479	0.568	....	0.479
Drop test (1-inch screen):					
Held..........per cent..	48.0	56.5	40.0	....	61.0
Passed..........do....	52.0	43.5	60.0	....	39.0
Tumbler test (1-inch screen):					
Held..........do....	87.0	78.5	90.0	....	80.0
Passed (fines)..........do....	13.0	21.5	10.0	....	20.0
Fines through 10-mesh sieve..........do....	84.4	92.6	100.0	....	85.2
Absorption test:					
Time immersed..........days..	8	10	9	....	23
Water absorbed..........per cent..	13.9	15.8	14.0	....	19.5
Average for first 7 days..........do....	....	2.07	....	....	....
Average for first 5 days..........do....	2.42	....	2.4	....	2.68
Specific gravity (apparent)..........	1.165	1.177	1.280	....	1.148

Chemical analyses of coal and briquets.

	Car sample.	Raw fuel.	Test 196.	Test 197.	Test 200.
Laboratory No..........	4509	4490	5061	4755	5052
Proximate:					
Air-drying loss..........per cent..	4.10	8.10	....	5.10	....
Moisture..........do....	4.46	8.72	3.25	5.95	3.01
Volatile matter..........do....	15.44	....	18.17	18.41	17.84
Fixed carbon..........do....	71.63	....	69.87	67.00	70.53
Ash..........do....	8.47	....	8.71	8.64	8.62
Sulphur..........do....	1.49	....	1.42	1.34	1.38
Ultimate:					
Hydrogen..........do....	4.50	....	4.12	4.16	4.13
Carbon..........do....	81.05	....	81.41	80.41	82.27
Nitrogen..........do....	1.34	....	1.19	1.19	1.27
Oxygen..........do....	2.68	....	2.81	3.63	2.02
Extract by CS_2 (as received)..........do....	....	.69	5.44	5.61	4.68
Pitch in briquet by analysis..........do....	....	....	5.36	5.56	4.51
Heat value..........B. t. u..	13,682	....	14,029	13,442	13,946

Chemical analyses of coal and briquets—Continued.

	Tests 201 and 202.	Tests 205 and 232.	Test 236.	Test 238.	Test 239.
Laboratory No	4512	5049	4797	4930	4932
Proximate:					
Air-drying loss .... per cent	3.90	....	3.80	1.00	0.90
Moisture .... do	4.05	2.41	4.71	1.83	1.30
Volatile matter .... do	19.68	19.41	18.43	15.05	13.73
Fixed carbon .... do	66.56	68.86	69.14	69.52	69.67
Ash .... do	9.71	9.32	7.72	13.60	13.50
Sulphur .... do	1.72	1.75	1.19	1.61	1.19
Ultimate:					
Hydrogen .... do	4.29	4.10	4.40	3.12	2.81
Carbon .... do	79.76	81.20	81.77	77.24	70.94
Nitrogen .... do	1.05	1.11	1.26	.70	.75
Oxygen .... do	2.99	2.25	3.22	3.48	8.79
Extract by CS_2 (as received) .... do	5.73	8.11	7.38	7.21	7.52
Pitch in briquet by analysis .... do	5.70	7.78	6.98	7.17	7.35
Heat value .... B. t. u.	13,547	13,937	13,873	13,185	12,787

	Test 240.	Test 243.	Test 250.	Rhode Island No. 1.	Miscellaneous No. 9.
Laboratory No	4977	4832	4906	3216	4763
Proximate:					
Moisture .... per cent	1.06	1.34	2.55	2.41	1.95
Volatile matter .... do	15.87	16.39	24.23	4.92	.89
Fixed carbon .... do	69.24	70.34	62.80	73.61	75.50
Ash .... do	13.83	11.93	10.42	19.06	21.66
Sulphur .... do	1.44	1.37	1.99	.07	.66
Ultimate:					
Hydrogen .... do	2.81	3.46	4.36	.65	....
Carbon .... do	76.02	77.79	78.64	76.95	....
Nitrogen .... do	.81	.53	.88	.17	....
Oxygen .... do	4.92	4.74	3.39	2.63	....

Extraction analyses.

	Pitches.			Fuel.		Briquets.		
				Rhode Island No. 1.	Miscellaneous No. 9.	Test 240.	Test 243.	Test 250.
Laboratory No	4625	4683	4806	3216	4763	4977	4832	4906
Air-drying loss ... per cent	....	....	....	2.00	1.30	....	0.70	1.70
Extract by CS_2 (as received) per cent	90.56	89.31	96.90	.02	.15	7.43	8.84	7.96
Pitch in briquet by analysis .... per cent	....	....	....	....	....	7.14	9.41	7.33
Heat value .... B. t. u.	16,576	16,637	16,864	10,996	10,870	12,721	13,387	13,680

PENNSYLVANIA NO. 19.

Bituminous run-of-mine coal from the Pittsburgh bed one-fourth mile north of Herminie, Westmoreland County, on the Pennsylvania Railroad, was designated Pennsylvania No. 19, and a part of the sample was used in briquetting tests 218, 219, and 242. Steaming test 508 was made of equal quantities of briquets from briquetting tests 218 and 219.

In tests 218, 219, and 242 the size of coal used was as follows: Over one-fourth inch, 3 per cent; one-tenth inch to one-fourth inch, 8.8 per cent; one-twentieth inch to one-tenth inch, 17 per cent; one-fortieth inch to one-twentieth inch, 26.3 per cent; through one-fortieth inch, 47.6 per cent.

Briquets with 6, 7, and 8 per cent of binder appeared equally satisfactory. Their edges were sharp, their surfaces hard and smooth, and their fracture clear with firm edges. Renfrow briquets had a glossy surface. All briquets stood handling and piling well.

Briquetting tests.

	Test No.		
	218.	219.	242.
Details of manufacture:			
Machine used	English.	English.	Renfrow No. 1.
Temperature of briquets °F.	185	185	149
Binder—			
Kind	W. G. P.	W. G. P.	W. G. P.
Laboratory No	4683	4683	4806
Amount per cent	6	7	8
Weight of			
Fuel briquetted pounds	8,000	4,000	4,000
Briquets, average do	3.65	3.74	0.431
Drop test (1-inch screen):			
Held per cent	73.8	78.5	78.5
Passed do	26.2	21.5	21.5
Tumbler test (1-inch screen):			
Held do	75.6	78.8	91.5
Passed (fines) do	24.4	21.2	8.5
Fines through 10-mesh sieve do	70.0	65.0	90.09
Absorption test:			
Time immersed days	13	13	10
Water absorbed per cent	8.6	8.4	7.9
Average for first 8 days do	1.0	1.0	1.0
Specific gravity (apparent)	1.124	1.133	1.125

Chemical analyses of coal and briquets.

	Car sample.	Tests 218 and 219.	Test 242.
Laboratory No	4489	4648	4828
Proximate:			
Moisture per cent	3.39	5.12	1.75
Volatile matter do	31.79	33.00	33.50
Fixed carbon do	56.46	54.36	55.24
Ash do	8.36	7.52	9.51
Sulphur do	1.05	1.05	1.36
Ultimate:			
Hydrogen do	4.85	4.76	4.52
Carbon do	77.03	77.93	75.91
Nitrogen do	1.44	1.41	1.35
Oxygen do	6.94	6.86	7.16

Extraction analyses.

	Pitches.		Fuel.	Briquets.	
			Pa. No. 19.	Tests 218 and 219.	Test 242.
Laboratory No	4683	4806	4489	4648	4828
Air-drying loss per cent	....	....	2.40	4.00	0.50
Extracted by CS_2 (as received) do	89.31	96.90	....	5.80	9.16
Pitch in briquet by analysis do	....	....	....	5.71	8.21
Heat value B. t. u.	16,637	16,864	13,699	13,540	13,646

PENNSYLVANIA NO. 20.

Semibituminous run-of-mine coal from the Lower Kittanning or B bed, 1½ miles east of Seward, Westmoreland County, on the Pennsylvania Railroad, was designated Pennsylvania No. 20, and a part of the sample was used in briquetting tests 198, 208, 209, 212, 213, 215, and 216. Steaming test 512 was made with equal weights of briquets from briquetting tests 215 and 216. Steaming test 514 was made with equal weights of briquets from tests 208 and 209.

In tests 198, 208, and 209 the size of coal used was as follows: Over one-fourth inch, 0.8 per cent; one-tenth inch to one-fourth inch, 3.6 per cent; one-twentieth inch to one-tenth inch, 11.2 per cent; one-fortieth inch to one-twentieth inch, 27 per cent; through one-fortieth inch, 57.4 per cent. Briquets from both machines had similar appearance, with smooth, hard surface; were very brittle and broke with a glossy fracture and sharp edges. The percentage of binder seemed to have little effect on their brittleness, although Renfrow briquets, with 8 per cent of binder, handled with less breakage.

In tests 212, 213, 215, and 216 washed coal was used in sizes as follows: Over one-fourth inch, 0.8 per cent; one-tenth inch to one-fourth inch, 4.8 per cent; one-twentieth inch to one-tenth inch, 16 per cent; one-fortieth inch to one-twentieth inch, 26 per cent; through one-fortieth inch, 52.4 per cent. There was no noticeable difference between the briquets from this test and those made from raw coal.

Briquetting tests.

	Test No.						
	198.	208.	209.	212.	213.	215.	216.
Details of manufacture:							
Machine used	English.	Renfrow No. 1.	Renfrow No. 1.	Renfrow No. 1.	Renfrow No. 1.	English.	English.
Temperature of briquets, °F.	158	158	158	158	158	176	176
Binder—							
Kind	W. G. P.	W. G. P.	W. G. P.	W. G. P	W. G. P.	W. G. P.	W. G. P.
Laboratory No	4683	4683	4683	4683	4683	4683	4683
Amount, per cent	6	7	8	7	8	6	7
Weight of—							
Fuel briquetted, pounds	3,200	4,500	8,000	6,500	6,500	6,400	3,300
Briquets, average, pounds	3.52	0.451	0.457	0.427	0.458	3.63	3.44
Drop test (1-inch screen):							
Held, per cent	74.8	19.5	26.0	23.0	19.5	74.6	71.9
Passed, per cent	25.2	80.5	74.0	77.0	80.5	25.4	28.1
Tumbler test (1-inch screen):							
Held, per cent	71.0	54.0	61.5	67.0	64.0	74.0	70.0
Passed (fines), per cent	29.0	46.0	38.5	33.0	36.0	26.0	29.5
Fines through 10-mesh sieve, per cent	65.4	86.8	86.4	91.6	87.3	63.2	70.4
Absorption test:							
Time immersed, days	13	13	13	13	13	13	13
Water absorbed, per cent	14.5	15.5	15.5	19.0	14.5	9.5	11.0
Average for first 5 days, per cent	2.34	2.78	2.66	3.1	2.50	1.56	1.56
Specific gravity (apparent)	1.141	1.11	1.127	1.043	1.144	1.148	1.121

Chemical analyses of coal and briquets.

	Raw fuel.	Washed fuel.	Test 198.	Tests 208 and 209.	Test 212.	Test 213.	Tests 215 and 216.
Laboratory No	4517	4498	4769	4713	4726	4885	4726
Proximate:							
Moisture........per cent..	4.00	3.98	6.16	2.79	3.50	1.23	3.50
Volatile matter........do....	15.89	28.13	19.23	21.11	19.98	20.58	19.98
Fixed carbon........do....	69.57	57.73	64.38	67.79	67.71	67.74	67.71
Ash........do....	10.54	10.16	10.23	8.31	8.81	10.45	8.81
Sulphur........do....	2.85	1.00	2.68	1.91	1.59	2.98	1.59
Ultimate:							
Hydrogen........do....	4.53	4.71	4.20	4.42	4.39	4.56	4.39
Carbon........do....	78.55	76.38	78.12	80.25	81.06	79.21	81.06
Nitrogen........do....	1.17	1.59	1.09	1.09	1.06	1.12	1.06
Oxygen........do....	1.80	5.70	2.83	3.73	2.72	1.51	2.72

Extraction analyses.

	Pitch.	Fuel.		Briquets.				
				Test 198.	Tests 208 and 209.	Test 212.	Test 213.	Tests 215 and 216.
Laboratory No	4683	4517	4498	4769	4713	4726	4885	4726
Air-drying loss........per cent..	....	3.60	3.10	5.50	2.00	3.10	0.60	3.10
Extract by CS_2 (as received).do....	89.31	....	0.99	5.29	6.72	6.61	7.98	6.61
Pitch in briquet by analysis.do....	....	....	....	5.00	6.49	6.37	7.92	6.37
Heat value........B. t. u..	16,637	13,347	13,311	13,198	13,981	13,988	13,896	13,988

PENNSYLVANIA NO. 22.

Bituminous run-of-mine coal from the Pittsburgh bed at Huff, Westmoreland County, on the Pennsylvania Railroad, was designated Pennsylvania No. 22 and a part of the sample was used in briquetting tests 211, 222, and 223. Steaming test 510 was made of equal weights of briquets from briquetting tests 222 and 223.

In tests 211, 222, and 223 the size of coal used was as follows: Over one-fourth inch, 1.6 per cent; one-tenth inch to one-fourth inch, 17.8 per cent; one-twentieth inch to one-tenth inch, 33.4 per cent; one-fortieth inch to one-twentieth inch, 23.2 per cent; through one-fortieth inch, 24 per cent. English briquets with 7 per cent of binder showed better outer surface than those with 6 per cent of binder. The surfaces of all the briquets were hard, clean, sharp, and glossy, with characteristic fracture. Renfrow briquets dropped from the conveyor belt without breakage.

Briquetting tests.

	Test No.		
	211.	222.	223.
Details of manufacture:			
Machine used	Renfrow No.1.	English.	English.
Temperature of briquets °F	158	185	158
Binder—			
Kind	W. G. P.	W. G. P.	W. G. P.
Laboratory No	4683	4683	4683
Amount per cent	7	7	6
Weight of—			
Fuel briquetted pounds	4,000	19,000	3,200
Briquets, average do	0.442	3.87	3.93
Drop test (1-inch screen):			
Held per cent	54.5	79.8	62.2
Passed do	45.5	20.2	37.8
Tumbler test (1-inch screen):			
Held do	85.0	73.7	67.8
Passed (fines) do	15.0	26.3	32.2
Fines through 10-mesh sieve do	90.8	65.0	70.0
Absorption test:			
Time immersed days	13	13	13
Water absorbed per cent	11.7	9.6	8.9
Average for first 5 days do	1.78	1.48	1.38
Specific gravity (apparent)	1.110	1.160	1.164

Chemical analyses of coal and briquets.

	Raw fuel.	Test 211.	Test 222.	Test 223.
Laboratory No	4498	4684	4704	4706
Proximate:				
Moisture per cent	3.98	2.21	5.15	3.55
Volatile matter do	28.13	32.11	29.60	30.57
Fixed carbon do	57.73	55.12	55.08	54.27
Ash do	10.16	10.56	10.17	11.61
Sulphur do	1.00	1.13	1.17	1.07
Ultimate:				
Hydrogen do	4.71	4.53	4.46	3.55
Carbon do	76.38	75.71	75.40	75.94
Nitrogen do	1.59	1.39	1.39	1.24
Oxygen do	5.70	6.41	6.80	6.12

Extraction analyses.

	Pitch.	Fuel.	Briquets.		
		Pa. No. 22.	Test 211.	Test 222.	Test 223.
Laboratory No	4683	4498	4684	4704	4706
Air-drying loss per cent		3.10	1.10	4.00	2.30
Extract by CS_2 (as received) do	89.31	.76	6.77	5.45	6.20
Pitch in briquet by analysis do			6.78	5.30	6.09
Heat value B. t. u.	16,637	13,311	13,561	13,183	13,275

PENNSYLVANIA—JAMESTOWN NO. 18.

The coal designated Jamestown No. 18 was anthracite coal of buckwheat size and was briquetted in a mixture with Jamestown No. 11 coal in test 290. The data obtained from this test are presented in the section entitled "West Virginia—Jamestown No. 11."

PHILIPPINE ISLANDS—PITTSBURGH NO. 112.

A sample of 5 tons of run-of-mine subbituminous from Batan Island, one of the Philippine Islands, was furnished by the Bureau of Insular Affairs, War Department, for tests and was designated Pittsburgh No. 112. A part of the sample was tested on the hydraulic-laboratory press and later two series of tests of the coal were made under the writer's supervision at the plant of the Indianapolis Pressed Fuel Co., Indianapolis, Ind., as the English machine of the briquetting section was not in condition to make these tests and as the use of the commercial plant was kindly offered by G. W. Ladley, secretary and treasurer of the company.

The fuel has a structure similar to bituminous coal and yet the analysis would indicate that it is a lignite, although very near the subbituminous classification, the carbon-hydrogen ratio of the coal being 10: .66. This coal is very weak and easily crushed to the fineness desired for briquetting. On account of its structural weakness briquetting was expected greatly to improve this fuel, making it stronger, of better heating value, and of better weather-resisting qualities.

The first series of tests at the plant of the Indianapolis Pressed Fuel Co. was made of fuel that had been dried and crushed at the Pittsburgh plant of the bureau. The second series of tests at the Indianapolis plant was made of fuel that had been crushed at the Pittsburgh plant of the bureau but had not been dried. Two varieties of tests were made in each series, namely: (1) Tests (331 to 346) in which the material was mixed and run through the Indianapolis plant in the regular manner. (2) Tests (347 to 353) in which the material was mixed, heated in small lots, and placed in molds of the Ladley press by hand, being pressed in the usual manner.

The tests made by the first method were not so successful as those made by the second method in which the mixture of fuel and binder was heated in small lots and placed in the molds by hand, as the machine was adjusted and proportioned for pressing bituminous coal. Therefore the length of travel of the plungers was not sufficient properly to compress a spongy material like the Philippine lignite when the molds were filled in the usual manner. This result should not be considered a fault of the machine, as with a different cam the same machine could be adapted to compress a lignite properly.

A description of the Ladley press used for these tests is given on page 36.

The small quantity of fuel available for these tests (only 5 tons) did not allow as wide a range of tests on the Ladley press as could be desired, but the results obtained were sufficient to determine that this coal can be made into excellent briquets with some of the binder used in the tests.

The relative weather-resisting qualities of the different briquets are shown by the results of the absorption test, in which the briquets were immersed in water and the percentage of water absorbed determined daily. Briquets that do not go to pieces quickly in the absorption test will stand the weather well.

The amount of moisture, the size of coal used, and the numbers of tests made on each of the two lots is shown below:

Tests on subbituminous coal from Batan Island, P. I.

Series of tests.	First.	Second.	
		Lot A.	Lot B.[a]
Test Nos	331–341	342–345	346–353
Percentage of moisture in fuel	7.22	17.99	17.99
Size as used:			
Over $\frac{1}{4}$ inch, per cent	1.0	11.2	1.0
$\frac{1}{4}$ to $\frac{1}{10}$ inch, do	14.0	29.0	14.0
$\frac{1}{10}$ to $\frac{1}{20}$ inch, do	30.0	29.3	30.0
$\frac{1}{20}$ to $\frac{1}{40}$ inch, do	27.7	17.5	27.7
Through $\frac{1}{40}$ inch, do	27.3	13.7	27.3

[a] Same sample as lot A, but lot B was screened through a $\frac{1}{4}$-inch screen to remove large pieces.

The data obtained at the Indianapolis tests are given in the following table:

Briquetting tests.

	Test No.				
	331.	332.	333.	334.	335.
Details of manufacture:					
Machine used	Ladley.	Ladley.	Ladley.	Ladley.	Ladley.
Briquetting temperature, °F	186	184	188	185	185
Binder—					
Kind	(a)	(a)	Cell pitch.	C. T. P.	C. T. P.
Laboratory No	34	34	9298	12009	12009
Amount, per cent	6	10	10	6	8
Weight of—					
Fuel briquetted, pounds	200	400	150	400	400
Briquet, average, ounces	8	8	7.5	6.5	6.5
Moisture in briquet mixture, per cent	14.08	13.65	12.50	14.76	20.29
Drop test (1-inch screen):					
Held, do	0.0	56	26	2	24
Passed, do	100.0	44	74	98	76
Absorption test:					
Time immersed, days	0.5	0.5	0.5	20	23
Water absorbed, per cent	See text.	See text.	See text.	28.36	36.11
Average for first 4 days, do	....	....	....	4.97	8.33
Specific gravity (apparent)	1.098	1.163	1.068	0.958	0.892

[a] Sulphite liquor.

Briquetting tests—Continued.

	Test No.				
	336.	337.	338.	339.	340.
Details of manufacture:					
Machine used	Ladley.	Ladley.	Ladley.	Ladley.	Ladley.
Briquetting temperature °F	200	208	194	195	195
Binder—					
Kind	C. T. P.	C. T. P.	C. T. P.	C. T. P.	C. T. P.
Laboratory No.	12009	12009	12009	12009	12009
Amount per cent	7	6	6.5	5.5	4
Weight of—					
Fuel briquetted pounds	800	500	1,600	400	200
Briquet, average ounces	7	7	7	6.5	6.5
Moisture in briquet mixture per cent	11.48	11.60	11.84	14.01	14.72
Drop test (1-inch screen):					
Held do	6	3	15	4	([a])
Passed do	94	97	85	96	....
Absorption test:					
Time immersed days	20	20	20	16	14
Water absorbed per cent	24.96	29.53	30.38	31.02	24.71
Average for first 3 days do	3.38	5.19	5.59	6.17	4.85
Specific gravity (apparent)	1.024	0.971	0.960	0.936	0.945

	Test No.				
	341.	342.	343.	344.	345.
Details of manufacture:					
Machine used	Ladley.	Ladley.	Ladley.	Ladley.	Ladley.
Briquetting temperature °F	200	200	201	200	176
Binder—					
Kind	Cell pitch.	W. G. P.	W. G. P.	Flour.	W. G. P.
Laboratory No.	9298	12010	12010	11976	12010
Amount per cent	12	6	8	8	10
Weight of—					
Fuel briquetted pounds	400	200	200	250	250
Briquet, average ounces	7	8	7	8	7
Moisture in briquet mixture per cent	15.18	23.56	23.67	25.31	24.09
Drop test (1-inch screen):					
Held do	77	0.0	12.0	43	34
Passed do	23	100	88	57	66
Absorption test:					
Time immersed days	0.5	5	14	0.5	12
Water absorbed per cent	See text.	13.78	19.31	See text.	18.65
Average for first 4 days do	....	4.26	4.70	....	5.12
Specific gravity (apparent)	1.059	1.096	1.059	1.177	1.052

	Test No.				
	346.	347.	348.	349.	350.
Details of manufacture:					
Machine used	Ladley.	Ladley.	Ladley.	Ladley.	Ladley.
Briquetting temperature °F	135	210	[b] 158	[b] 158	210
Binder—					
Kind	W. G. P.	W. G. P.	W. G. P.	W. G. P.	Flour.
Laboratory No.	12010	12010	12010	12010	11976
Amount per cent	10	6	8	10	8
Weight of—					
Fuel briquetted pounds	250	200	25	20	50
Briquet, average ounces	8	8.5	9	10.5	10
Moisture in briquet mixture per cent	20.79	14.12	16.46	16.30	11.79
Drop test (1-inch screen):					
Held do	11	([c])	([c])	32	([c])
Passed do	89	([d])	....	68	....
Absorption test:					
Time immersed days	14	15	20	20	0.5
Water absorbed per cent	22.02	18.97	19.16	18.49	See text.
Average for first 4 days do	5.70	4.19	4.13	3.90	....
Specific gravity (apparent)	1.049	1.061	1.067	1.086	1.158

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[a] There were not enough briquets to make this test.
[b] Heated over gasoline stove.
[c] There were not sufficient briquets for this test.
[d] Tests Nos. 347 to 353 were heated in small lots and filled into molds by hand.

Briquetting tests—Continued.

	Test No.		
	351.	352.	353.
Details of manufacture:			
Machine used	Ladley.	Ladley.	Ladley.
Briquetting temperature °F.	210	210	210
Binder—			
Kind	W. G. P.	(a)	(a)
Laboratory No	12010	(b)	(b)
Amount per cent.	10	6 and 6	5 and 5
Weight of—			
Fuel briquetted pounds.	20	400	100
Briquet, average do.	10	10	9.5
Moisture in briquet mixture per cent.	19.01	19.23	19.50
Drop test (1-inch screen):			
Held do.	(c)	94	88
Passed do.	6	....	12
Absorption test:			
Time immersed days.	14	3	2
Water absorbed per cent.	14.30	8.31	12.05
Average for first 4 days do.	3.63	2.77	....
Specific gravity (apparent)	1.108	1.189	1.150

[a] W. G. P. and flour.
[b] 12010 and 11976.
[c] There were not enough briquets to make this test.

Chemical analyses of coal and briquets.

	Raw fuel.	Raw fuel.[a]	Test 331.	Test 332.	Test 333.
Laboratory No	11114	11975	12037	12038	12039
Proximate:					
Air-drying loss per cent.	5.7	6.60	6.80	4.90	4.50
Moisture do.	20.08	17.99	14.08	13.65	12.50
Volatile matter do.	36.73	37.48	35.48	37.70	38.16
Fixed carbon do.	36.66	35.00	41.13	39.94	40.43
Ash do.	6.53	9.53	9.31	8.71	8.91
Sulphur do.	1.43	1.58	1.96	1.87	2.02
Ultimate:					
Hydrogen do.	4.67	4.40	....	....	....
Carbon do.	66.33	62.46	....	....	....
Nitrogen do.	1.25	1.27	....	....	....
Oxygen do.	17.79	18.32	....	....	....
Extract by CS_2 (as received) do.	1.79	....	....	....	....
Heat value B. t. u.	9,176	8,822	9,727	9,565	9,842
Specific gravity	1.318	....	....	....	....

	Test No.				
	334.	335.	336.	337.	338.
Laboratory No	12040	11520	11518	11517	11521
Air-drying loss per cent.	5.90	16.30	5.40	5.20	6.20
Moisture do.	14.76	20.29	11.48	11.60	11.84
Volatile matter do.	36.35	33.13	39.85	40.65	39.95
Fixed carbon do.	40.36	38.34	39.60	39.92	39.53
Ash do.	8.53	8.24	9.07	7.83	8.68
Sulphur do.	1.62	1.58	1.66	1.57	1.58
Heat value B. t. u.	9,655	9,230	9,950	10,109	9,923

[a] Analysis of second lot of fuel tested at Indianapolis plant.

Chemical analyses of coal and briquets—Continued.

	Test No.				
	339.	340.	341.	342.	343.
Laboratory No	12041	12042	11519	11962	11963
Air-drying loss ... per cent	4.40	5.00	9.40	16.60	14.80
Moisture ... do	14.01	14.72	15.18	23.56	23.67
Volatile matter ... do	38.67	37.97	39.70	32.43	34.30
Fixed carbon ... do	39.37	39.24	36.12	34.90	33.64
Ash ... do	7.95	8.07	9.00	9.11	8.39
Sulphur ... do	1.55	1.48	1.94	1.92	1.53
Heat value ... B. t. u.	9,754	9,594	9,169	8,743	8,658

	Test No.				
	344.	345.	346.	347.	348.
Laboratory No	11964	11966	11967	11968	11969
Air-drying loss ... per cent	16.00	15.60	10.70	2.40	4.90
Moisture ... do	25.31	24.09	20.79	14.12	16.46
Volatile matter ... do	33.04	34.38	37.18	38.96	38.15
Fixed carbon ... do	33.19	33.01	33.33	37.28	36.57
Ash ... do	8.46	8.52	8.70	9.64	8.82
Sulphur ... do	1.54	1.47	1.50	1.60	1.51
Heat value ... B. t. u.	8,307	8,730	9,036	9,639	9,497

	Test No.				
	349.	350.	351.	352.	353.
Laboratory No	11970	11971	11972	11973	11974
Air-drying loss ... per cent	3.60	1.00	9.50	9.30	5.40
Moisture ... do	16.30	11.79	19.01	19.23	19.50
Volatile matter ... do	38.36	41.88	39.26	40.02	38.03
Fixed carbon ... do	36.50	37.35	33.22	32.40	34.05
Ash ... do	8.84	8.98	8.51	8.35	8.42
Sulphur ... do	1.53	1.59	1.50	1.43	1.40
Heat value ... B. t. u.	9,531	9,293	9,241	8,822	8,930

A series of laboratory experiments, 45 in number, was also made on this fuel. The results are discussed on pages 79 to 84.

In test 331 coal and thick sulphite liquor were mixed with shovels after the liquor had been softened with steam from the steam jet. The mixture was run into the measuring machine and then through the rest of the plant. The briquets made were soft and did not have sufficient binder. Therefore 6 per cent of sulphite liquor is not sufficient for this material. When air-dried, the briquets were very soft and crumbly, the shape was spoiled, and the surfaces were badly rubbed off by transportation. In the absorption test the briquets went to pieces in water a few hours after immersion.

In test 332 fuel and sulphite liquor were mixed by hand after the binder had been melted by heating it in the water bath and applying steam from the steam jet. The materials balled considerably in the mixing. The briquets were a decided improvement on those made with 6 per cent of binder, but were not very strong when just made. It was indicated that with a proper dryer for the briquets a satisfactory briquet can be made with this binder. After standing a day the briquets were firm and strong; hence 10 per cent of sulphite liquor was sufficient to make a satisfactory briquet of this coal; 14 per cent would be better if the briquets were not to be used immediately. In the absorption test the briquets went to pieces a few hours after immersion.

In test 333 coal and ground pitch were mixed by means of shovels, were thrown through the chute into the coal compartment of the measuring machine, and were heated by the steam heater, after which the mixture was pressed in the usual way. The briquets were weak when fresh and seemingly there was not sufficient quantity of the material (150 pounds) to fill the boxes properly. Some of the material was put into the molds by hand and compressed, making much stronger briquets. When air-dried the shape was good, the edges were fair, and the strength was fair; the surfaces rubbed off somewhat too easily. In the absorption test the briquets went to pieces a few hours after immersion.

In test 334 the fuel and pitch were mixed cold and fed into the measuring machine. When freshly made the briquets were not very strong, and it appeared that the mold boxes were not properly filled. Some of the briquets were fairly satisfactory, however, and 6 per cent of this binder may be sufficient. When air-dried the shape of the briquets was poor, the surfaces were rough and crumbly, and the edges brittle and weak. These briquets were unsatisfactory, being very weak. They resisted the water in the absorption test very well, but the amount of water absorbed indicated too much porosity and an insufficient compression. The briquets were lighter than water.

In test 335 the fuel and the pitch were mixed by hand and fed into the measuring machine. The briquets were stronger than those made with 6 per cent of binder, but 8 per cent was seemingly more than was necessary. The surfaces of the briquets were rough and there was too much moisture present. When air-dried, the shape of the briquets was poor, the surfaces were rough and crumbly, and the edges weak. The briquets were not satisfactory, being very weak. They were lighter than water and the water absorbed in the absorption test indicated too much porosity and too little compression.

In test 336 pitch and coal were mixed by hand and fed into the measuring machine, a large amount of material being used so that the mold might fill better. The machine was stopped by the action of the pitch, few briquets being obtained. The shape of the air-dried briquets was poor, the surfaces were rough and very crumbly, and the edges very weak. The briquets stood the absorption test well and should resist weathering well.

In test 337 fuel and a binder of coal-tar pitch were mixed dry and shoveled into the measuring machine. The briquets were fairly strong when fresh, and seemingly had sufficient pitch and an excess of water. The shape of the air-dried briquets was very poor, the surfaces were very rough and crumbly, and the edges rounded and crumbly. The briquets were weak and wore away very easily. The absorption test indicated that the briquets were too porous and required more compression. They were lighter than water.

In test 338 fuel and pitch were mixed by hand and fed into the measuring machine. The briquets were run out to the belt conveyor, but the fan was not working, and few of them were good as they fell off the end of the belt. A second lot was mixed and sent through with the fan running to cool the briquets, which were better than those of the previous lot. Coal and pitch were mixed for a third batch. The shape of the air-dried briquets was fairly good. Their surfaces were slightly rough and were not easily affected by rubbing, although they were somewhat rubbed as a result of shipment. The edges were slightly rounded but fairly firm. The strength of the briquets was good. They were too porous, required more compression, and were lighter than water.

In test 339 fuel and a binder of coal-tar pitch were mixed and fed into the measuring machine. This lot of briquets when fresh was seemingly as strong as those made with 6.5 per cent of binder. The shape of air-dried briquets was poor; their surfaces were rough and badly rubbed and easily crumbled; the edges were worn round, crumbled easily, and were weak. The briquets broke easily, were too porous, and lighter than water.

Test 340 furnished briquets that looked well when they came from the press but had little strength to resist handling. When air-dried they were the worst briquets of the lot. Their shape was lost, their surfaces were crumbled irregularly, and what remained of the briquets was soft and crumbly. Their edges were completely rounded away by rubbing in shipping. The briquets were very weak, were too porous, and were lighter than water.

In test 341 coal and cell pitch were mixed and sent through the machine. When air-dried, the briquets had a very good shape; the surfaces were fairly smooth and not easily rubbed; their edges, although slightly rounded, were firm, and the briquets were the strongest ones made to date from this fuel. In the absorption test the briquets went to pieces a few hours after immersion and therefore would not stand weathering well.

In test 342 coal and water-gas pitch were mixed cold and run through the heater. The mixture appeared too wet for the best results. The briquets were soft when fresh. When air-dried the briquets had a good shape; their surfaces were rough and showed the effect of too large pieces in the mixture as the roughness did not extend over the whole surface; their edges were rounded and crumbly; the briquets were weak. The briquets resisted water well in the absorption test and absorption was complete in five days after immersion.

In test 343 coal and water-gas pitch were mixed cold and passed through the heater. The briquets appeared too wet and indicated that the amount of steaming should be reduced. When air-dried, the briquets were better than the previous lot, but their surfaces were rough and crumbly; their shape was fair; their edges were crumbly, rounded, and weak. The briquets were weak, resisted water well, but were too porous.

In test 344 flour and coal were mixed and heated in the heater before being pressed. The briquets were fairly firm when fresh, but were not very smooth on their surfaces and rubbed off too easily. When air-dried, their shape was very good, their surfaces were smooth and not easily rubbed, and their edges were sharp and rather firm. The briquets resisted water poorly and went to pieces a few hours after immersion.

In test 345 coal and pitch were mixed and fed into the middle of the heater by hand. This mixture required one-half minute to go through the heater. The briquets were fairly strong when fresh, but were rough on their surfaces and did not have enough compression. When air-dried their shape was very poor, their surfaces very rough but not easily crumbled, and their edges rough and rounded but firm. The strength of the briquets was good. The briquets possessed good water-resisting qualities but were too porous.

In test 346, to determine what effect the size of the material had on the briquets, two sacks of coal were screened through a $\frac{1}{4}$-mesh screen. Then coal and pitch were mixed and run into the middle of the heater before being pressed. There was not much difference between these briquets and the briquets of test 345. When air-dried their shape was poor, their surfaces were rough but not easily crumbled, and their edges were rough and rounded but nevertheless were rather firm. The strength of the briquets was good. They resisted water well but would have been improved by a higher compression in the mold.

In test 347 the briquetting mixture was heated with steam from the steam jet and placed in the molds by hand. The briquets were fairly strong when fresh, but when cold they rubbed too easily and indicated too little binder. When air-dried their shape was poor, their surfaces were very rough and easily crumbled, and their edges rounded and soft. The briquets were weak. The briquets from this test resisted water well.

In test 348 the mixture was heated over a gasoline stove. The briquets had good form and surfaces but were too easily affected by rubbing to be entirely satisfactory. When air-dried their shape was good and their surfaces were fairly smooth, but could be crumbled too easily; the edges were rounded on some of the briquets but sharp on others and were moderately firm; the strength of the briquets was fairly good, but more binder was needed. The briquets resisted water well in the absorption test.

In test 349 the briquetting mixture was heated over a gasoline stove and placed in the molds by hand. The briquets could be handled when fresh, but were not entirely satisfactory on account of the ease with which their surfaces rubbed off. When air-dried their shape was good; their surfaces were slightly rough but firm; their edges were very slightly rounded yet firm; their strength was good. The briquets resisted water well.

In test 350 the briquetting mixture was dried and heated with steam from the steam jet for one-quarter minute before being placed in the molds by hand. The briquets had an excellent appearance when fresh and were strong enough to stand handling. After having stood for one hour they did not have as sonorous a sound when struck together as those made with pitch binder. When air-dried their shape was excellent, their surfaces smooth and firm, and their edges sharp and firm. The briquets were very strong, but they did not resist the bad effects of water well, as in the absorption test they went to pieces a few hours after immersion.

In test 351 the briquetting mixture was heated with steam from the steam jet, instead of with dry heat as in test 346. After heating for one-quarter minute the mixture was placed in the molds by hand. The briquets were a decided improvement over those made with dry heat (test 346) and were strong enough to stand handling. When cold, the briquets had a satisfactory appearance and strength and did not rub to pieces as much as some of the briquets from previous tests. They had excellent water-resisting qualities and absorbed less water than those from test 346, in which less compression was obtained.

In test 352 the briquetting mixture was heated with steam from the steam jet for one-quarter minute and placed in the molds by hand. The briquets had an excellent appearance and strength when fresh and would not rub off easily. When cold, they were the best made from this fuel, having firm, hard surfaces and sharp, firm edges. They could not be broken in the hands. They stood the water-absorption test only three days, but probably would have sufficient weather-resisting qualities for commercial conditions.

In test 353 the briquetting mixture was heated one-quarter of a minute with steam from the steam jet and fed into the molds by hand. The briquets were strong enough for all purposes when fresh, and would unquestionably stand the handling incident to being placed in storage. The cold briquets had excellent appearance and strength. Little difference was noticeable between them and the briquets made with 6 per cent of flour and 6 per cent of water-gas pitch (test 352). Either of these two briquets equals in appearance those made from Indiana coal. They stood two days' immersion in water before going to pieces, and may therefore be sufficiently weather-resisting to meet commercial conditions.

SUMMARY OF RESULTS OF TESTS OF PHILIPPINE COAL.

CRUSHING.

The Philippine coal itself is very weak and should be finely ground before briquetting (the fineness of corn meal will be sufficiently fine), as the binder, in order to be effective, must coat very small particles. Then, even if when the pressure is applied the small particles should break, the briquets would not be weakened materially.

In this respect the briquetting of this coal differs from the briquetting of anthracite and bituminous coal, for the latter are strong in themselves and all that is required of the binder is that it cement the particles of the coal together, as the individual particles are strong enough to stand the briquetting pressure without breaking.

In the case of the Philippine coal, the high pressure necessary to unite the particles by means of the binder is sufficient to crush coal particles of much size, with a consequent weak briquet; hence a liquid binder should have an especial advantage for briquetting this coal, as it would tend to be absorbed into the particles of coal, and if they should be crushed by the briquetting pressure there would be sufficient binder present to keep the briquet from becoming weak.

EFFECTS OF DRYING.

Briquets made from the undried fuel possessed greater strength than those made from the dried fuel. This difference is seemingly due to the fact that when moisture is removed from this fuel by drying, the physical strength of the fuel is decreased, and when pressure is applied to the mixture in making briquets, particles of coal are crushed, and some binders are not fluid enough to penetrate into the porous structure of the fuel, as for example, coal-tar and water-gas pitch; hence the crushed particles have no binder to cement them together and the briquets are weak.

It was noticed that the larger pieces of dried coal could be crushed in the hand, whereas pieces of the undried coal of the same size were much stronger. In tests L 95[a] and L 101[a], 6 per cent of water-gas pitch was used. In test L 95 of the undried coal the briquets had a crushing strength of 950 pounds per square inch, whereas in test L 101 the crushing strength was only 600 pounds, or about twothirds that of the briquet made from the undried fuel. Comparing test L 96, using 4 per cent of water-gas pitch and undried fuel, with test L 100, using 4 per cent of water-gas pitch but dried coal, it is found that the crushing strength is as 500 to 175, or nearly 3 to 1. When 8 per cent of pitch is used, the difference in strength between the briquets made from the undried fuel and the ones made from the dried fuel is not so great, the crushing strength of the former being 1,240 pounds per square inch, and that of the latter 1,100 pounds per square inch. A comparison of the briquets made with starch binder shows an even greater difference in strength between the briquets made from the undried and the dried fuel. Comparing test L 104, made with 5 per cent of starch and dried fuel, with test L 139, made with 5 per cent of starch and undried fuel, the dried-fuel briquets had a crushing strength of less than 50 pounds per square inch, whereas the undried-fuel briquets had a crushing strength of 775 pounds. With flour binder the briquets made with undried fuel were also much stronger than those made with dried fuel. Of all the briquets made, those in which flour was the binder had the greatest strength. The briquets of test 352, made with 6 per cent each of water-gas pitch and flour, were the strongest of all, and in a drop test 94 per cent of the briquets was held on a 1-inch screen after five drops. Those made by test 353 were almost as strong as those of the previous test, as they stood a drop test with 88 per cent held by the 1-inch screen. Tests 332 and 341, made respectively with 6 per cent of sulphite liquor and 12 per cent of cell pitch, furnished briquets of a satisfactory strength.

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[a] See p. 80.

COMPRESSIBILITY.

Laboratory tests of this coal show that reduction in volume of the briquetting mixture under a pressure of 6,000 pounds per square inch varies from 35 to 45 per cent, with an average of 41.7 per cent.

BINDER REQUIRED.

As a result of these tests it was found that this fuel could not be satisfactorily briquetted without binder, even when a pressure of 30,000 pounds per square inch was used.

On account of the porosity of this fuel and its structural weakness, a larger proportion of binder is required to make it into satisfactory briquets than is required for bituminous coals.

PROPORTION OF BINDER REQUIRED.

According to laboratory briquetting tests, 7 per cent of the kind of water-gas pitch used would be sufficient to make briquets of satisfactory strength; briquets made with 8 per cent of this pitch showed an excess of binder, whereas briquets made with 6 per cent were not quite strong enough. The tests made with the Ladley press indicate that a higher percentage of water-gas pitch would be required to make a commercial briquet—probably 10 to 12 per cent.

Tests with the Ladley machine indicated that 8 per cent of coal-tar pitch is not sufficient to produce briquets of satisfactory strength. It should be said, however, that with more compression on the machine 8 per cent of coal-tar pitch might be found to be sufficient.

Flour binder made stronger briquets from this fuel than any other one binder, but briquets made with flour binder alone did not stand the water as well as those made with pitch alone or with a compound binder of pitch and flour.

Ten per cent of sulphite liquor furnished a briquet of sufficient strength but deficient in water-resisting qualities. Twelve per cent of cell pitch produced a briquet of sufficient strength but deficient in water-resisting qualities.

More than 5 per cent of starch binder would be required to produce a briquet of satisfactory strength, and probably 8 to 10 per cent would be sufficient. None of the binders used gave satisfactory results with the dried fuel.

HEAT VALUES.

The heat values of briquets made with dried fuel were 1 to 8 per cent higher than the fuel as received at the plant, this increase of heat value being largely due to the decrease of moisture present. The briquets made from the undried fuel showed an improvement in heat value of 5 to 8 per cent when the briquets were allowed to stand for a few days after being made. The heat value of the briquets is approximately 9,500 British thermal units per pound.

RHODE ISLAND NO. 1.

Graphitic anthracite run-of-mine coal from Cranston, Providence County (near Providence), was designated Rhode Island No. 1, and a part of the sample was used in mixture with Utah No. 1 coal in briquetting test 127, with Utah No. 2 coal in briquetting test 133, with Pennsylvania No. 15 in briquetting test 184, and with Pennsylvania No. 18 in briquetting test 243. Steaming tests 414 and 415 were made of briquets from briquetting test 127, and steaming test 416 was made of briquets from briquetting test 133.

Analyses of this fuel and details of the briquetting tests are presented in the sections dealing with the coals with which this fuel was mixed as mentioned in the preceding paragraph.

RHODE ISLAND—PITTSBURGH NO. 19.

A sample of four barrels of run-of-mine graphitic anthracite coal from Cranston mine, Cranston, Providence County, was designated Pittsburgh No. 19, and briquetting test 316 was made with this sample. The briquets made in this test were delivered for steaming tests to the company furnishing the sample of coal.

Excellent briquets were made with 6 per cent of pitch. Even less binder might have been sufficient, but the small quantity of the sample permitted making only one test on the English machine. However, laboratory tests on the hydraulic press indicated that 4 per cent of binder is sufficient to produce a strong and satisfactory briquet.

It will be noted that the briquets had a very high specific gravity owing to the high specific gravity of the coal used. The briquets obtained were very strong and difficult to fracture and had firm edges. A smoother briquet could have been made if the material used had been fine slack or more finely ground, but the sample used was too hard to be ground fine by the equipment available at the time of the test. As all of the briquets made were sent away, no drop or tumbler tests could be made of them.

Briquetting tests.

	Test 316.		Test 316.
Size as shipped	r. o. m.	Details of manufacture—Contd.	
Size as used:		Binder—	
Over $\frac{1}{4}$ inch ... per cent	6.0	Kind	W. G. P.
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch ... do	40.0	Laboratory No.	5940
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch ... do	22.0	Amount ... per cent	6
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch ... do	13.0	Weight of—	
Through $\frac{1}{40}$ inch ... do	19.0	Fuel briquetted ... pounds	810
Details of manufacture:		Briquets, average ... do	4.78
Machine used	English.	Specific gravity (apparent)	1.764
Briquetting temperature ... °F	162		

Chemical analyses of coal and briquets.

	Raw fuel.	Test 316.
Laboratory No.	7790	7843
Moisture ... per cent	4.51	2.31
Volatile matter ... do	3.46	4.69
Fixed carbon ... do	59.67	70.02
Ash ... do	32.36	22.98
Sulphur ... do	.12	.29

Extraction analyses.

	Pitch.	Fuel.	Briquets.
		R. I. No. 1.	Test 316.
Laboratory No.	5940	7790	7843
Air-drying loss ... per cent	....	4.00	....
Extract by CS^2 (as received) ... do	96.60	....	....
Heat value ... B. t. u.	16,780	8,411	10,247

TENNESSEE NO. 1.

Bituminous run-of-mine coal from Fork Ridge, Claiborne County, on the Louisville & Nashville Railroad, was designated Tennessee No. 1, and 18,600 pounds of the washed sample was used in briquetting test 130. Steaming tests 409 and 411 were made of briquets from briquetting test 130.

Briquets made on the English machine with 5 and 6 per cent of binder were good and firm; their edges and surfaces were harder with 6 per cent than with 5 per cent of binder. The fractures of both were sharp and clear.

Briquets made on the Renfrow machine with 6 and 6.5 per cent of binder showed dull fracture, their edges broke easily, and their surfaces were too soft. Those made with 7 per cent of binder were satisfactory, having a clear fracture and sharp edges; they broke without crumbling.

Briquetting tests.

	Test No.				
	130A.	130B.	130C.	130D.	130E.
Size as shipped	R. o. m.	R. o. m.	R. o. m.	R. o. m.	R. o. m.
Size as used:					
Over $\frac{1}{4}$ inch..per cent..	2.5	2.5	2.5	2.5	2.5
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch.do....	7.7	7.7	7.7	7.7	7.7
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch, per cent	17.8	17.8	17.8	17.8	17.8
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch, per cent	24.1	24.1	24.1	24.1	24.1
Through $\frac{1}{40}$ inch, per cent	47.9	47.9	47.9	47.9	47.9
Details of manufacture:					
Machine used	English.	English.	Renfrow No. 1.	Renfrow No. 1.	Renfrow No. 1.
Briquetting temperature..°F..	180	180	149	149	149
Binder—					
Kind	W. G. P.	W. G. P.	W. G. P.	W. G. P.	W. G. P.
Laboratory No....	3410	3410	3410	3410	3410
Amount.per cent..	5	6	6	6.5	7
Average weight of briquet, pounds.	3.28	3.28	0.50	0.50	0.50
Drop test (1-inch screen):					
Held........per cent..	84.4	....	....	....	....
Passed...........do....	15.6	....	....	....	....
Weather test:					
Time exposed...days..	201	201	201	201	201
Condition	B	B	B	B	B

Chemical analyses of coal and briquets.

	Test 130.	Test 130.
Laboratory No.	....	....
Proximate:		
Moisture...per cent..	2.62	1.99
Volatile matter...do....	37.09	36.56
Fixed carbon...do....	54.32	54.14
Ash...do....	5.97	7.30
Sulphur...do....	1.17	1.12
Ultimate:		
Hydrogen...do....	5.08	4.84
Carbon...do....	79.02	77.39
Nitrogen...do....	1.70	1.53
Oxygen...do....	6.87	7.64

Extraction analyses.

	Pitch.	Fuel.	Briquets.
		Tenn. No. 1.	Test 130.
Laboratory No	3410		
Air-drying loss per cent		3.50	1.00
Extract by CS_2 (as received) do	79.98	2.15	4.54
Pitch in briquet by analysis do			3.07
Heat value B. t. u.	16,478	12,569	13,723

TENNESSEE NO. 4.

Bituminous run-of-mine coal from a mine situated 3 miles north of Oliver Springs, Roane County, on the Louisville & Nashville Railroad, was designated Tennessee No. 4, and a part of the sample was used in briquetting test 120; part was mixed with miscellaneous No. 5 (coke breeze) in briquetting tests 150 and 151. Steaming test 405 was made of briquets from briquetting test 120.

In test 120, briquets made on the English machine at a temperature of 179.6° F., with an average weight of 3.3 pounds and with 5 per cent of binder, were easily broken, showing cracks with soft edges; briquets made with 5.5 per cent of binder showed improvement, but the edges were not sharp, and the briquets were easily broken; those with 6 per cent of binder were satisfactory, showing firm edges, hard surfaces, and clean, sharp fracture; those with 6.5 per cent of binder showed improvement in surfaces and edges. In the drop test with briquets containing 5 per cent of binder the 1-inch screen held 83.3 per cent; with 5.5 per cent of binder 85.4 per cent was held. Briquets made on the Renfrow machine, at a temperature of 149° F., an average weight 0.4 pound, and 6, 6.5, and 7 per cent of binder, had smooth, firm surfaces and slightly soft, though generally satisfactory, edges; 7.5 per cent of binder made the best briquet of the lot; all surfaces and fractures were entirely satisfactory.

In test 150, 80 per cent of Tennessee No. 4 and 20 per cent of miscellaneous No. 5 (coke breeze) were used. Briquets with 8 per cent of binder were satisfactory, with no difference in appearance from those made from Tennessee No. 4 alone. They were tough when warm, easily handled and stored, and had rough but hard surfaces. The briquets were difficult to break, and the fracture was uneven, although the edges were firm. The structure was porous.

In test 151, 75 per cent of Tennessee No. 4 and 25 per cent of miscellaneous No. 5 were used. With the increased percentage of coke breeze the briquets were easily broken when warm, although they were sufficiently tough after cooling.

Briquetting tests.

	Test No.		
	120.	150.	151.
Size as used:			
Over $\frac{1}{4}$ inch...per cent..	3.2	3.2	3.2
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch...do....	11.4	10.9	10.9
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch...do....	19.9	18.6	18.6
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch...do....	25.0	25.8	25.8
Under $\frac{1}{40}$ inch...do....	40.0	41.5	41.5
Details of manufacture:			
Machine used...	(a)	Renfrow No. 1.	Renfrow No. 1.
Temperature of briquets...°F..	(a)	149	149
Binder—			
Kind...	W. G. P.	W. G. P.	W. G. P.
Laboratory No...	3410	3410	3410
Amount...per cent..	(a)	8	8
Weight of—			
Fuel briquetted...pounds..	44,000	40,000	40,000
Briquets, average...do....	(a)	.532	.513
Weathering test:			
Time exposed...days..	214	214	214
Condition...	B	B	B

[a] See notes preceding table.

Chemical analyses of coal and briquets.

	Tennessee No. 4.	Miscellaneous No. 4.	Test 120.	Test 150.	Test 151.
Laboratory No...	3058	3386	....	3380	3367
Proximate:					
Moisture...per cent..	6.39	10.72	2.88	2.55	2.71
Volatile matter...do....	32.32	4.08	35.78	31.91	29.56
Fixed carbon...do....	51.76	73.25	53.84	57.42	58.41
Ash...do....	9.53	11.95	7.50	8.12	9.32
Sulphur...do....	.98	1.02	.91	.92	.93
Ultimate:					
Hydrogen...do....	5.02	....	4.73	4.34	4.15
Carbon...do....	74.95	....	77.93	78.53	78.40
Nitrogen...do....	1.67	....	1.79	1.71	1.67
Oxygen...do....	7.13	....	6.89	6.15	5.60

Extraction analyses.

	Pitch.	Fuel.		Briquets.		
		Tennessee No. 4.	Miscellaneous No. 5.	Test 120.	Test 150.	Test 151.
Laboratory No...	3410	3058	3386	....	3380	3367
Air-drying loss...per cent..	....	4.70	8.80	1.10	0.60	0.60
Extracted by CS_2 (as received)...do....	79.98	1.38	.59	5.75	6.23	6.52
Pitch in briquet by analysis...do....	....	....	....	5.56	7.29	7.51
Heat value...B. t. u..	16,478	12,578	11,036	13,578	13,536	13,154

TENNESSEE NO. 7B.

Bituminous slack coal, through a plate perforated with one-fourth by 1 inch holes, from Wilder, Fentress County, on the Southern Railway, was designated Tennessee No. 7B, and 7,000 pounds of the washed sample was used in briquetting test 121. Steaming test 406 was made of the briquets from briquetting test 121.

Briquets with 5.5 and 6 per cent of binder had firm edges, but their surfaces were slightly crumbly when rubbed; they broke with a clean fracture, leaving a firm surface; those with 6.5 and 7 per cent of binder had hard and smooth surfaces, with a hard and firm fracture. Not enough coal was furnished to make briquetting tests on the Renfrow No. 1 machine or steaming tests of unbriquetted fuel.

Briquetting tests.

	Test No.			
	121A.	121B.	121C.	121D.
Size as used:				
Over $\frac{1}{4}$ inch..........per cent..	1.8	....	....	....
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch..........do....	10.8	....	....	....
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch..........do....	19.0	....	....	....
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch..........do....	21.0	....	....	....
Through $\frac{1}{40}$ inch..........do....	47.4	....	....	....
Details of manufacture:				
Machine used..........	English.	English.	English.	English.
Briquetting temperature..........°F..	179.6	179.6	179.6	179.6
Binder—				
Kind..........	W. G. P.	W. G. P.	W. G. P.	W. G. P.
Laboratory No..........	3410	3410	3410	3410
Amount..........per cent..	5.5	6	6.5	7.0
Average weight of briquet..........pounds..	3.08	3.08	3.08	3.08
Drop test (1-inch screen):				
Held..........per cent..	78.3	79.9	89.5	95.2
Passed..........do....	21.7	20.1	10.5	4.8
Weather test:				
Time exposed..........days..	200	200	200	200
Condition..........	B	B	B	B

Chemical analyses of coal and briquets.

	Car sample.	Test 121.
Laboratory No..........	3186	....
Proximate:		
Moisture..........per cent..	7.51	3.37
Volatile matter..........do....	31.74	35.80
Fixed carbon..........do....	50.63	50.77
Ash..........do....	10.12	10.06
Sulphur..........do....	2.26	2.09
Ultimate:		
Hydrogen..........do....	....	5.02
Carbon..........do....	....	75.58
Nitrogen..........do....	....	1.36
Oxygen..........do....	....	5.47

Extraction analyses.

	Pitch.	Fuel.	Briquets.
		Tenn. No. 7B.	Test 121.
Laboratory No..........	3410	3186	....
Air-drying loss..........per cent..	....	6.10	1.80
Extracted by CS_2(as received)..........do....	79.98	1.84	6.05
Pitch in briquet by analysis..........do....	....	....	5.39
Heat value..........B. t. u..	16,478	12,447	13,090

Chemical analyses of coal and briquets.

	Car sample 9B.	Car sample 9C.	Test 122.
Laboratory No.	3114	3115	3338
Proximate:			
Moisture ... per cent.	5.68	4.68	4.24
Volatile matter ... do.	25.36	28.75	29.80
Fixed carbon ... do.	50.41	57.31	56.10
Ash ... do.	18.55	9.26	9.86
Sulphur ... do.	0.74	0.65	0.79
Ultimate:			
Hydrogen ... do.	4.65	4.74	4.60
Carbon ... do.	64.87	77.48	77.00
Nitrogen ... do.	1.27	1.30	1.43
Oxygen ... do.	5.16	6.09	5.84

Extraction analyses.

	Pitch.	Fuel.		Briquets.
		Tenn. No. 9B.	Tenn. No. 9C.	Test 122.
Laboratory No.	3410	3114	3115	3338
Air-drying loss ... per cent.		4.70	3.30	2.50
Extracted by CS_2 (as received) ... do.	79.98	0.19		5.31
Pitch in briquet by analysis ... do.				6.41
Heat value ... B. t. u.	16,478	11,480	13,163	13,047

TENNESSEE NOS. 9B AND 9C (WASHED SLACK).

Bituminous slack coal from Coalmont, Grundy County, on the Nashville, Chattanooga & St. Louis Railway, was designated Tennessee No. 9B after washing, and 14 tons of slack as shipped was designated Tennessee No. 9C. A mixture of 9B and 9C was used in briquetting test 122. Steaming test 393 was made of briquets from the above test.

In test 122 the size of the coal used was as follows: Over one-fourth inch, 1.2 per cent; one-tenth inch to one-fourth inch, 5.5 per cent; one-twentieth to one-tenth inch, 12.5 per cent; one-fortieth inch to one-twentieth inch, 23.8 per cent; through one-fortieth inch, 57 per cent. The English machine was used, the temperature of the briquets being 179.6° F.; kind of binder, water-gas pitch; laboratory number, 3410; weight of fuel briquetted, 14,400 pounds; average weight of briquets, 3.24 pounds.

With 5.4 and 5.6 per cent of binder, the briquets were fairly good, but somewhat crumbly at the edges. With 6.6, 7, and 8 per cent of binder, the outer surfaces were very firm and smooth, the fracture was coarse but not crumbly, and the broken surfaces were very hard. In the drop test, with 7 per cent of binder, the 1-inch screen held 85.6 per cent. In the weathering test the condition of all binders after being exposed 222 days was B. Not enough coal was furnished to make briquets on the Renfrow No. 1 machine for comparative tests.

TENNESSEE NO. 10.

Bituminous slack coal from a mine located 1 mile north of Orme, Marion County, on the Nashville, Chattanooga & St. Louis Railway, was designated Tennessee No. 10. A part of the sample was used in briquetting test 128. Steaming tests 407 and 408 were made of the briquets from the above test.

In test 128 the details were as follows: Condition of coal, 1-inch slack, washed; kind of binder, water-gas pitch; laboratory number, 3410; weight of fuel briquetted, 35,400 pounds. The briquets made with the three percentages of pitch (5.5, 6.5, and 6.7) were all good.

Briquets made on the English machine at a temperature of 175° F. and with 5.5 per cent of binder had an average weight of 3.63 pounds and could be roughened slightly by rubbing; their outer surfaces crumbled slightly when broken. Briquets with 6 and 6.5 per cent of binder could be roughened slightly by rubbing; their outer surfaces were hard and smooth, and their broken surfaces very hard and rough. In the drop test of briquets with 5.5 per cent of binder the 1-inch screen held 81.7 per cent, with 6 per cent of binder the screen held 90.1 per cent, and with 6.5 per cent of binder the screen held 89.1 per cent. In the weathering test all briquets were exposed 203 days, when their condition was B.

Renfrow No. 1 machine briquets made at 149° F. with 6 per cent of binder had an average weight of 0.53 pound and showed crumbly, fractured surfaces. With 6.5 per cent of binder the briquets were tougher and did not break as easily, and broken surfaces were firm, but the briquets seemed to lack pitch. In the weathering test briquets with both binders were exposed 204 days, when their condition was B.

Chemical analyses of coal and briquets.

	Fuel.	Test 128.	Test 128.
Laboratory No	3359		
Proximate:			
Moisture ... per cent	7.02	2.46	2.88
Volatile matter ... do		30.89	30.84
Fixed carbon ... do		51.80	49.55
Ash ... do	13.75	14.85	16.73
Sulphur ... do	.98	1.02	.96
Ultimate:			
Hydrogen ... do		4.47	4.56
Carbon ... do		71.53	69.82
Nitrogen ... do		1.30	.92
Oxygen ... do		6.43	6.48

Extraction analyses.

	Pitch.	Fuel, Tenn. No. 10.	Briquets, test 128.
Laboratory No	3410	3359	
Air-drying loss ... per cent		5.20	1.3
Extracted by CS_2 (as received) ... do	79.98	1.32	6.98
Pitch in briquet by analysis ... do			7.19
Heat value ... B. t. u	16,478	11,596	11,920

TEXAS NO. 4.

Lignite run-of-mine coal from Hoyt, Wood County, on the Missouri, Kansas & Texas Railway, was designated Texas No. 4. A part of the sample was used in briquetting test 112 at St. Louis. The briquets were too unsatisfactory for use in steaming tests. No analysis was made of the briquets.

The details of test 112 were as follows: Machine used, English; temperature of briquets, 179.6° F.; kind of binder, coal-tar pitch; laboratory number, 2933; percentage of binder, 5, 6, 7, and 8 per cent; weight of fuel briquetted, 4,500 pounds.

The briquets were of a brown color and full of cracks. The different percentages of binder had no relative effect on their firmness; all fell apart when the pitch hardened. None burned well or was satisfactory. They did not swell nor crack, but gradually disintegrated in the fire, burning slowly with characteristic lignite sparking. In the weathering test all briquets were exposed 75 days, when their condition was D.

The unsatisfactory results obtained with this fuel were probably due to the excessive proportion of moisture present. With the English machine it was impossible to control the moisture added in the mixing and softening of the pitch, and as no drying was done before briquetting, the affinity of lignite for moisture caused a large absorption of moisture; as the briquets cooled they also dried to some extent, resulting in the cracking of the briquets mentioned above. With the lignite dried sufficiently before briquetting and with a suitable mixer and press, much more satisfactory briquets could probably have been made from this fuel, as the results obtained were in large measure due to the unsuitability of the briquetting equipment for use with lignite.

Chemical analysis.

	Car sample.		Car sample.
Laboratory No.	2717	Ultimate:	
Proximate:		Hydrogen ... per cent..	4.41
Moisture ... per cent..	33.85	Carbon ... do....	65.18
Volatile matter ... do....	27.50	Nitrogen ... do....	1.07
Fixed carbon ... do....	31.35	Oxygen ... do....	17.53
Ash ... do....	7.30		
Sulphur ... do....	.51		

Extraction analyses.

	Pitch.	Fuel, Tex. No. 4.
Laboratory No.	2933	2717
Air-drying loss ... per cent..	....	26.70
Extracted by CS_2 (as received) ... do....	64.20	....
Heat value (as received) ... B. t. u..	15,937	7,497

TEXAS—PITTSBURGH NO. 7.

A 3-car shipment of lignite from the Big Lump mine, 3½ miles northeast of Rockdale, Milam County, Tex., was designated Pittsburgh No. 7.

House-heating boiler tests H23, H24, H30, H45, and H46 were made of this fuel, but the larger part of the shipment was used in preliminary briquetting experiments to adjust the drier, cooler, and press of the German plant. This lot was the first to arrive at the Pittsburgh testing station. Considerable difficulty was experienced in making it into briquets, and the shipment was exhausted before satisfactory results were obtained. It is hoped that further tests of this lignite may be made under more favorable conditions.

Mr. Lehmann, the representative of the German company that furnished the lignite-briquetting plant, remained at Pittsburgh until the plant was in good working condition. The tests of the first sample of lignite were therefore under his direction. Most of these tests were preliminary, and it was impossible to obtain a complete record of them, so only a general statement of conditions and results can be given.

The briquetting material in the various tests contained different proportions of water, ranging from 2.3 to 11.2 per cent, and different pressures, from very light to the heaviest possible, were applied to it. From some of the tests the briquets were poorly formed, rough, and scaly, but were fairly strong; from other tests the briquets were well formed but weak.

Only one cohesion (drop) test was made of the briquets obtained, because most of the tests gave only pieces of briquets. In the one test made only 24 per cent was held by a 1-inch screen.

The best briquets were made by using material that contained 11.2 per cent of moisture and applying a rather light pressure. The results seemed to show that for the best results with the German machine the ground and dried lignite should contain between 8 and 12 per cent of moisture, and that the pressure used should be moderate—about that obtained by using a set of dies so ground that in a length of about 80 mm. the decrease in height would be 3 to 4 mm.

As a general conclusion, it may be said that this lignite is deficient in natural binding material, and although it can be briquetted without artificial binder on a machine of the type used, such a machine did not make briquets of satisfactory form and strength from it. To determine the best conditions for briquetting, further tests are needed. It is probable that the lignite will make entirely satisfactory briquets if an artificial binder and a different type of press are used.

The following proximate analyses show the changes in composition of the sample during transportation from the mine to the plant, a period of 29 days, and after storage at the plant for 17 and 38 days, respectively:

Chemical analyses.

	Mine sample.	Car sample.	Plant samples.	
			After 17 days.	After 38 days.
Date taken	Feb. 1	Mar. 1	Mar. 18	Apr. 8
Laboratory No.	7270	7350	7433	7554
Proximate:				
Air-drying loss per cent	31.50	25.10	25.70	25.30
Moisture do	35.30	33.38	31.72	30.98
Volatile matter do	26.22	27.44	26.81	29.04
Fixed carbon do	29.58	29.62	31.97	30.41
Ash do	8.90	9.56	9.50	9.57
Sulphur do	.76	.94	.91	.92
Ultimate:				
Hydrogen do		4.59		
Carbon do		62.01		
Nitrogen do		1.01		
Oxygen do		16.63		
Extract by CS_2 (moisture free) do		1.23		1.16
Heat value B. t. u.	6,898	7,189	7,423	7,301

TEXAS—PITTSBURGH NO. 8.

A sample shipment, 2 cars, of ½-inch lump lignite from the Carr mine No. 3, 2 miles southwest of Lytle, Medina County, Tex., was designated Pittsburgh No. 8 and was tested on the German press without binder.

This lignite had a dark-brown color. It weathered very rapidly, exposure to a single rainstorm causing lumps to crack in all directions. After it had been wet and dried a few times the sample crumbled entirely to slack.

Gas-producer test 180 and briquetting tests 293, 295, and 296 were made of this fuel, and several preliminary briquetting tests for adjusting the German press when being installed were also made.

Several preliminary tests were made under the direction of Mr. Lehmann. In the first of these, with a steam pressure of 5 pounds in the drier, the percentage of moisture in the fuel was reduced from 30 per cent to 11.2 per cent. A rather low pressure in the molds produced well-formed but weak briquets.

Material containing 10 per cent of moisture, and subjected to a high pressure, furnished briquets that had poor form and rough surfaces, but they were much stronger than those made in the first test. The roughness of surface was largely caused by steam (generated while the briquet was being formed under high pressure) that blew out around the sides of each briquet just before it left the mold. The dust blown out by the steam was disagreeable to breathe and at times formed clouds that darkened the whole room.

In the next test, material containing 8.4 per cent of moisture was subjected to a high pressure. The briquets were better formed and smoother than in the previous test, and were the strongest yet made from the lignite.

In the fourth test the material contained 6 per cent of moisture, but the same high pressure was used. The briquets were still better, being well formed and strong. Another test, with the material containing only 3.6 per cent of moisture, gave the best briquets obtained from this fuel. However, with this low-moisture content the mold pressure was too great for the press, and after an hour's run the main bearing of the connecting rod became so hot that the press had to be stopped.

The following table summarizes the essential data of the tests made with this sample of lignite:

Summary of tests.

Test No.	Moisture in briquet material.	Pressure in mold.	Character of briquets.		Remarks.
			Form.	Strength.	
	Per cent.				
Preliminary	11.2	Low	Good	Weak	Pressure insufficient.
Do	10.0	High	Poor	Strong	Briquets rough.
Do	8.4	do	Fair	do	
Do	6.0	do	Good	do	Better than previous lot.
Do	3.6	do	do	do	Best lot.
293	8.7	do	do	Good	
295	7.7	Very high	None made		Material too dry.
296	12.2	do	Fair	Weak	Material too fine.

In the first official test (293) the material contained 8.7 per cent of moisture, and a high pressure was applied. About 61 per cent of the material that reached the press was coarser than one-twentieth inch, but practically all of this 61 per cent passed through a screen with ¼-inch mesh. The results indicated that it is well to have the material as evenly sized as possible and containing little dust. If the proportion of dust is excessive, the material does not bind well and blows out of the mold when pressed. Even sizing is also desirable because it permits even drying. The writer believes that this fuel should be crushed so that it will all pass through a ¼-inch screen, about 60 per cent being retained on a $\frac{1}{20}$-inch screen.

In tests 295 and 296 the dies were set to give a very high pressure. In test 295 the briquetting material contained 7.7 per cent moisture and was probably too dry; it did not bind. but fell from the press in the form of powder, accompanied by clouds of dust.

In test 296 the dried material had 12.2 per cent of moisture. The material probably contained too much dust, for the briquets crumbled easily and were not strong enough to be handled.

Plates XVI to XXI show how the briquets from tests 293 and 296 withstood exposure to the weather.

This lignite was made into excellent briquets without the addition of any binder. The moisture content of the dried material should be between 8 and 10 per cent if a moderate pressure is used, but only about 5 per cent, or even less, if an extremely high pressure is used. For best results the writer recommends that the material be pulverized so that about 60 per cent of the particles are between one-fourth inch and one-twentieth inch in diameter, that it go to the press containing 10 per cent of moisture, and that the briquetting pressure be 20,000 pounds per square inch.

The best briquets made from this fuel had strength enough to stand handling. They took the shape of the mold well, their edges were firm, and they had jet-black, lustrous surfaces. Such briquets should make a satisfactory steam or household fuel. No steaming tests were made of either the raw or the briquetted lignite. The ash content (about 17 per cent) of the briquets is considerably higher than that of good-quality bituminous coal.

Briquetting this lignite should improve its heating value 30 to 40 per cent by reducing the percentage of moisture. On the assumption that in briquetting the uncombined moisture is reduced from 30 per cent to 10 per cent, 1 ton (2,000 pounds) of raw fuel will make 1,600 pounds of briquets, or 2,500 pounds of raw fuel will make 1 ton of briquets. The raw fuel has a heating value of 6,800 British thermal units per pound and the briquetted fuel has a heating value of 9,300 British thermal units; therefore the fuel value of the briquets is 37 per cent higher than that of the raw fuel. Moreover, the briquets have the following additional advantages over raw fuel:

(*a*) Being of uniform size, they burn more freely and give off less smoke, a decided merit when used as a household fuel in a residence district.

(*b*) The briquets resist the effects of the weather much better than the raw fuel, and therefore can be stored for a longer time without serious deterioration. The briquets are not, however, much more waterproof than the raw fuel, and should be stored under cover; there they will remain in perfect condition for several months at least, whereas the raw fuel under similar conditions will disintegrate rapidly.

(*c*) The cost of transporting the briquetted fuel should be only 80 per cent of the cost of transporting enough raw fuel to furnish the same heating value.

Briquetting tests.

	Test No.		
	293.	295.	269.
Size as shipped	½″ lump.	½″ lump.	½″ lump.
Size as used:			
Over ¼ inch ... per cent	0.5	0.5	0.5
$\frac{1}{10}$ inch to ¼ inch ... do	30.5	18.0	18.0
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch ... do	30.0	28.5	28.5
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch ... do	24.5	21.0	21.0
Through $\frac{1}{40}$ inch ... do	14.5	32.0	32.0
Details of manufacture:			
Machine used	German.	German.	German.
Briquetting temperature ... °F	90	94	101
Binder used	None.	None.	None.
Tangent of die angle	5.5/89	6/89	6/89
Steam pressure on drier ... pounds	13	15	11
Weight of—			
Fuel briquetted ... do	11,440	None.	4,840
Briquets, average ... do	0.9	....	0.7
Moisture in briquet mixture ... per cent	8.73	7.68	12.17
Drop test (1-inch screen):			
Held ... do	44	(a)	(b)
Passed ... do	66	....	....
Tumbler test (1-inch screen):			
Held ... do	37	....	(b)
Passed ... do	63	....	....
Fines through 10-mesh sieve ... do	74	....	....
Weather test:			
Time exposed when examined ... days	66	....	....
Condition when examined	D	....	....

[a] No briquets.

[b] Briquets too weak for cohesion test.

The changes in composition of the lignite during transportation from the mines to the plant (25 days) and during storage (42 days) at the plant till used for one of the last tests are shown by the following analyses; analyses of the briquets or briquetting mixture are also included:

Chemical analyses of coal and briquets.

	Mine sample.	Car sample.	Sample as used on last test.	Test 293.	Test 293.[a]	Test 296.
Date taken	Feb. 5.	Mar. 2.	Apr. 13.	....	....	....
Laboratory No	7330	7461	7584	7583	7585	7623
Proximate:						
Air-drying loss ... per cent	24.20	26.30	19.40	1.50	....	....
Moisture ... do	32.92	30.77	28.00	8.07	5.02	9.96
Volatile matter ... do	27.42	27.36	27.50	37.31	38.53	37.84
Fixed carbon ... do	27.08	28.39	32.30	35.87	37.81	35.99
Ash ... do	12.58	13.48	12.20	18.75	18.64	16.21
Sulphur ... do	1.46	1.62	1.60	1.97	2.18	1.98
Ultimate:						
Hydrogen ... do	....	4.20	....	....	....	....
Carbon ... do	....	57.58	....	....	....	....
Nitrogen ... do	....	1.04	....	....	....	....
Oxygen ... do	....	15.37	....	....	....	....
Extract by CS_2 (moisture free) ... do	....	....	1.91	1.98	....	2.14
Heat value ... B. t. u	6,840	7,079	7,580	9,306	....	9,223

[a] Analysis of the material which flaked off from the surface of the briquets.

TEXAS—PITTSBURGH NO. 9.

A sample shipment, 3 cars, of ¾-inch lump lignite from the Calvert mine, 6 miles west of Calvert, Robertson County, Tex., was designated Pittsburgh No. 9.

Gas-producer tests 181 and 182, house-heating boiler tests H41 and H43, and briquetting tests 297, 320, 321, 323, 327, and 328 were made with the German lignite press, using the raw lignite without binder.

Test 297 did not yield any briquets. Seemingly the pressure in the mold was excessive; there may have been too little moisture in the material or the die angle may have been too great.

In test 320 a high pressure was used. The briquets were poorly formed and too weak to stand handling. The moisture content of the material was manifestly too high for the pressure used. Much dust was blown out around the sides of each briquet.

In test 321 the same pressure was used, but the material was still too moist and no satisfactory briquets were obtained. The briquets made had poor forms and were too weak to stand handling.

The material was drier in test 323 than in tests 297, 320, and 321, and contained only 3 per cent of moisture when it reached the machine. It was also finer. This material, however, stalled the press. After several attempts to operate the machine the test was stopped and the material remaining in the hopper was thrown away.

In test 327 the material was dried less than in test 323, and contained 4.6 per cent moisture when it reached the machine. The dies were changed so as to give less pressure. The briquets obtained were better than those made in test 323, but although they had good form they lacked strength, and crumbled when handled.

In the next test (328) the percentage of moisture in the briquetting material was raised to 6.4 per cent with beneficial results. The same pressure was used as in test 327. The briquets were the best so far obtained, but they were not strong enough to stand handling. The test was not completed, however, for a strong steel brace having a cross section of 3 by 5½ inches snapped and put the press out of operation until another brace could be forged. The tests were suspended before other pressures could be tried.

Following is a summary of the most important features of the tests of this sample of lignite:

Summary of tests.

Test No.	Moisture in briquet material.	Pressure in mold.	Character of briquets.		Remarks.
			Form.	Strength.	
	Per cent.				
327	4.6	High	Good	Weak	Too much moisture.
328	6.4	do	do	do	Better than test 327.
297	7.0	do	None made		Too much pressure.
323	3.0	Very high	do		Stalled machine; too little moisture and too much pressure.
321	6.4	do	Poor	Weak	Too much moisture and dust.
320	9.47	do	do	do	Do.

It will be seen that the moisture content in the briquetting material varied from 3 per cent to 9½ per cent. Two different pressures were used, but, although some of the tests gave briquets of good form, no briquets were of satisfactory strength.

To yield the best results with the German machine, this lignite should be ground so that it will all pass a ¼-inch screen, but about 60 per cent will be retained by a 1/20-inch screen; it should be dried till it contains 10 per cent of moisture. The die angle should be small enough to give a moderate pressure. However, the indications are that this lignite does not contain enough natural binder to make good briquets on the German press, and it should be tested with a little artificial binder on a press similar to the English machine. The writer is inclined to doubt whether this lignite can be briquetted at all without the addition of binding material. However, further tests should be made before a final conclusion is reached.

Briquetting tests.

	Test No.					
	297.	320.	321.	323.	327.	328.
Size as shipped	¾″ lump.	¾″ lump.	¾″ lump.	¾″ lump.	¾″ lump.	¾″ lump.
Size as used:						
Over ¼ inch ... per cent..	2.0	3.0	2.5	2.5	2.0	2.0
1/10 inch to ¼ inch ... do....	18.0	23.0	25.0	30.0	31.5	30.5
1/20 inch to 1/10 inch ... do....	30.0	28.0	28.5	28.5	29.0	30.5
1/40 inch to 1/20 inch ... do....	27.0	22.5	21.0	20.5	19.5	19.0
Through 1/40 inch ... do....	23.0	23.5	23.0	18.5	18.0	18.0
Details of manufacture:						
Machine used	German.	German.	German.	German.	German.	German.
Briquetting temperature ... °F..	84	100	102	97	93	116
Binder used	None.	None.	None.	None.	None.	None.
Tangent of die angle	6/89	7/89	7/89	7/89	6/89	6/89
Steam pressure on drier ... pounds..	10	4	10	15	10	12
Weight of —						
Fuel briquetted ... do....	None.	None.	None.	None.	None.	None.
Briquets, average ... do....						
Moisture in briquet mixture ... per cent..	6.98	9.47	6.40	3.0	4.6	6.4

The following proximate analyses show the changes in composition of this lignite during transportation from the mine to the plant, a period of 26 days, and in storage at the plant for 81 days until used for the last test. The fourth column gives an average of six analyses made on different dates.

Chemical analyses of coal and briquets.

	Mine sample.	Car sample.	Sample as used on last test.	Average of 6 samples.	Briquet 320.	Briquet 321.
Date taken	Mar. 6	Apr. 1	June 21	....	....	....
Laboratory No.	7403	7513	7950	....	7904	7941
Proximate:						
Air-drying loss ... per cent	29.30	25.40	12.10	13.17	....	....
Moisture ... do	34.33	29.62	23.50	24.01	9.04	7.92
Volatile matter ... do	25.94	27.60	29.07	29.75	37.22	37.33
Fixed carbon ... do	30.93	29.37	35.74	34.74	40.86	41.75
Ash ... do	8.80	13.41	11.69	11.50	12.88	13.00
Sulphur ... do	.95	.98	.82	.91	1.15	1.16
Ultimate:						
Hydrogen ... do	....	4.45	....	....	....	....
Carbon ... do	....	57.21	....	....	....	....
Nitrogen ... do	....	.98	....	....	....	....
Oxygen ... do	....	16.92	....	....	....	....
Extract by CS_2 (moisture free) ... do	....	....	....	1.28	....	1.14
Heat value ... B. t. u.	7,214	7,040	8,089	8,021	9,574	9,929

UTAH NO. 1.

Bituminous run-of-mine coal from a prospect on Huntington Creek, Carbon County, was designated Utah No. 1. A part of the sample as received at the plant was used in briquetting test 126; also in a mixture with Rhode Island No. 1 in briquetting test 127. Steaming tests 414 and 415 were made of briquets from test 127.

In test 126 the size of coal used was as follows: Over one-fourth inch, 1.4 per cent; one-tenth inch to one-fourth inch, 5.6 per cent; one-twentieth inch to one-tenth inch, 14.4 per cent; one-fortieth inch to one-twentieth inch, 25 per cent; through one-fortieth inch, 53 per cent. This coal was briquetted with low percentages of binder, with the idea of utilizing the natural resin (probably copalite) contained in the coal. With 4 and 5 per cent of binder the heat in the machine would not melt the natural resin, and the briquets were very deficient in binder and crumbled badly. With 6 per cent of binder the surfaces of whole briquets and of fractures crumbled. The use of a still higher percentage of pitch would improve the briquets. No drop tests were made of these briquets and no other regular data were obtained, on account of the small size of the sample.

In test 127 (with Rhode Island No. 1) the size of coal used was as follows: Over one-fourth inch, 1 per cent; one-tenth inch to one-fourth inch, 5.8 per cent; one-twentieth inch to one-tenth inch, 9.4 per cent; one-fortieth inch to one-twentieth inch, 26.4 per cent; through one-fortieth inch, 57.4 per cent. This test was made to prove the value of briquettng a good fuel with one that is commercially worthless. A high volatile coal low in ash was chosen to mix with the graphitic coal. Various percentages were tried, but 47 per cent of each coal and 6 per cent of binder made an entirely satisfactory briquet. Six per cent of binder made excellent briquets, whose outer surface was smooth, lustrous, and very hard. The briquets broke without crumbling, and the broken surfaces were smooth and hard.

Briquetting tests.

	Test 126.	Test 127.
Details of manufacture:		
Machine used	RenfrowNo. 1.	Renfrow No. 1.
Temperature of briquets °F	149	149
Binder—		
Kind	W. G. P.	W. G. P.
Laboratory No.	3410	3410
Amount per cent	4, 5, 6	6
Weight of—		
Fuel briquetted pounds	2,000	16,000
Briquets, average do	0.43	0.5
Weathering test:		
Time exposed days	214	214
Condition	C.	B.

Chemical analyses of coal and briquets.

	Utah No. 1.	Rhode Island No. 1.	Test 127.	Test 127.
Laboratory No.	3199	3216	....	....
Proximate:				
Air dry loss per cent	3.80	2.0	0.8	0.8
Moisture do	6.05	2.41	2.45	2.27
Volatile matter do	42.02	4.92	24.21	22.20
Fixed carbon do	47.06	73.61	62.60	65.29
Ash do	4.87	19.06	10.74	10.24
Sulphur do	.55	.07	.41	.41
Ultimate:				
Hydrogen do	5.42	.65	2.95	3.13
Carbon do	76.98	76.95	78.63	77.64
Nitrogen do	1.47	.17	.74	.74
Oxygen do	10.36	2.63	6.25	7.59
Extract by CS_2 (as received) do	3.83	.02	6.89	6.89
Pitch in briquets by analysis do	....	....	6.40	6.40
Heat valve B. t. u.	13,151	10,996	12,532	12,532

UTAH NO. 2.

Subbituminous slack (through 1¼-inch screen) from Coalville, Summit County, on the Union Pacific Railroad, was designated Utah No. 2. A part of the sample as received at the plant was used in briquetting test 132; part was mixed with Rhode Island No. 1 in briquetting test 133. Steaming tests 402 and 404 were made of briquets from briquetting test 132 and steaming test 416 of briquets from briquetting test 133.

In test 132 this coal, sent primarily for briquetting, had all the characteristics of lignite. Oil shale was sent to be used as a binder, but all efforts to use it for this purpose utterly failed. The briquets made on the English machine with 5 and 6 per cent of binder indicated a shortage of pitch; their outer surfaces were rough but crumbly and porous; they were crumbly at fractures, and broken and fractured surfaces were not firm. Briquets with 7 per cent of binder showed improvement over the others but were not satisfactory; their outer surface was harder but could be roughened by rubbing; they did not break clean. In the drop test, with 6 per cent of binder, the 1-inch screen held 54.4 per cent. The Renfrow briquets, with 6 per cent of binder, were soft and showed shortage of pitch. Those with 7 per cent of binder showed improvement. However, they broke with crumbly fracture and their broken surfaces were not firm. Eight per cent of binder made good briquets, with hard outer surface; they broke clean and their broken surfaces were firm.

In test 133 Rhode Island No. 1, the only available high volatile coal, was chosen for a test with a view to supplementing the data obtained in test 127. The test was not successful, as the coal showed characteristics of lignite, both in briquetting and in burning. The mixture contained 47 per cent of each coal. Briquets with 6 per cent of binder were tough and hard; their outer surface was smooth and very hard and their fracture rough but clean and firm. No drop tests were made.

Briquetting tests.

	Test 132.	Test 132.	Test 133.
Size as used:			
Over $\frac{1}{4}$ inch . . . per cent	0.8	. . . .	1.2
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch . . . do	8.0	. . . .	6.0
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch . . . do	21.4	. . . .	19.2
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch . . . do	29.8	. . . .	25.6
Through $\frac{1}{40}$ inch . . . do	40.0	. . . .	48.0
Details of manufacture:			
Machine used	English.	Renfrow No. 1.	Renfrow No. 1.
Briquetting temperature . . . °F	175	149	149
Binder—			
Kind	W. G. P.	W. G. P.	W. G. P.
Laboratory No	3410	3410	3410
Amount . . . per cent	6, 7, 8	5, 6, 7	6
Weight of—			
Fuel briquetted . . . pounds	29,000	29,000	37,000
Briquet, average . . . do	3.03	0.42	0.52
Weather test:			
Time exposed . . . days	190	190	190
Condition	D	C	E

Chemical analyses of coals and briquets.

	Utah No. 2.	Rhode Island No. 1.	Test 132.[a]	Test 132.[b]	Test 133.
Laboratory No	3259	3216	. . . . . .	. . . . . .	. . . . . .
Proximate:					
Moisture . . . per cent	12.66	2.41	11.53	9.32	5.85
Volatile matter . . . do	38.30	4.92	38.91	39.68	25.20
Fixed carbon . . . do	43.19	73.61	43.83	45.05	59.56
Ash . . . do	5.85	19.06	5.73	5.95	9.39
Sulphur . . . do	1.39	.07	1.36	1.37	.85
Ultimate:					
Hydrogen . . . do	. . . . . .	.65	4.70	4.75	2.94
Carbon . . . do	. . . . . .	76.95	72.15	73.30	76.42
Nitrogen . . . do	. . . . . .	.17	1.27	1.27	.73
Oxygen . . . do	. . . . . .	2.63	13.86	12.61	9.04

[a] Analysis of English briquets.

[b] Analysis of Renfrow briquets.

Extraction analyses.

	Pitch.	Fuel.		Briquets.	
		Utah No. 2.	Rhode Island No. 1.	Test 132.	Test 133.
Laboratory No.	3410	3259	3216	....	....
Air-drying loss .... per cent..	....	2.30	2.00	1.60	1.40
Extracted by CS_2 .... do....	79.98	.26	.02	4.61	6.06
Pitch in briquet by analysis .... do....	....	....	....	5.46	7.50
Heat value .... B. t. u..	16,478	10,697	10,996	11,180	11,527

VIRGINIA NO. 5B.

Semianthracite slack coal from the bed known as the "Big Seam" (Bush Mountain Field), 10 miles west of Blacksburg, Montgomery County, was designated Virginia No. 5B and the sample was used in briquetting tests 187 and 188. Steaming test 494 was made of equal weights of briquets from briquetting tests 187 and 188.

In tests 187 and 188 the size of coal used was as follows: Over one-fourth inch, 0.6 per cent; one-tenth inch to one-fourth inch, 8.8 per cent; one-twentienth inch to one-tenth inch, 23.6 per cent; one-fortieth to one-twentieth inch, 27.6 per cent; through one-fortieth inch, 39.4 per cent. A very hard, nonporous briquet was made with 6 per cent of binder on the English machine. Renfrow briquets with 7 per cent of binder stuck together when piled, showing excess of pitch; otherwise these briquets were satisfactory. This is an exceptionally good briquetting coal, requiring only a small percentage of binder and making briquets with firm, smooth outer surfaces, sharp edges, and characteristic glossy fracture.

Briquetting tests.

	Test 187.	Test 188.
Details of manufacture:		
Machine used	Renfrow No. 1.	English.
Briquetting temperature .... °F..	185	185
Binder—		
Kind	W. G. P.	W. G. P.
Laboratory No.	4543	4543
Amount .... per cent..	7	6.25
Weight of—		
Fuel briquetted .... pounds..	8,000	4,000
Briquet, average .... do....	0.457	4.11
Drop test (1-inch screen):		
Held .... per cent..	78.5	85.7
Passed .... do....	21.5	14.3
Tumbler test (1-inch screen):		
Held .... do....	94.0	89.3
Passed .... do....	6.0	10.7
Fines through 10-mesh sieve .... do....	96.9	79.1
Weather test:		
Time exposed .... days..	10	6
Condition	A	A
Absorption test:		
Time immersed .... days..	19	19
Water absorbed .... per cent..	14.8	12.6
Average for first 5 days .... do....	2.0	1.12
Specific gravity (apparent)	1.182	1.209

Chemical analyses of coal and briquets.

	Car sample.	Test 187.	Test 188.
Laboratory No	4294	4545	4417
Proximate:			
Moisture per cent	7.52	4.52	5.02
Volatile matter do	10.29	14.28	15.52
Fixed carbon do	65.96	65.93	64.51
Ash do	16.23	15.27	14.95
Sulphur do	.65	.79	.84
Ultimate:			
Hydrogen do	3.82	3.68	3.66
Carbon do	74.66	76.17	75.82
Nitrogen do	.75	.81	.88
Oxygen do	2.52	2.51	3.02

Extraction analyses.

	Pitch.	Fuel.	Briquets.	
		Va. 5B.	Test 187.	Test 188.
Laboratory No	4543	4294	4545	4417
Air-drying loss per cent		7.10	3.60	4.10
Extracted by CS_2 do	99.66	.27	6.24	5.74
Pitch in briquet by analysis do			6.01	5.51
Heat value B. t. u.	16,969	11,893	12,542	12,463

VIRGINIA—JAMESTOWN NO. 2

The sample designated as Jamestown No. 2 consisted of several cars of semibituminous run-of-mine coal from a mine working the Pocohontas No. 3 bed, Pocohontas, Tazewell County, Va., on the Norfolk & Western Railway.

Excellent briquets were made from this coal. Those made with 6 per cent of water-gas pitch binder (Lab. No. 5458) stood the cohesion tests as well as those made with 8 per cent of binder (Lab. No. 5563). The warm briquets from all four of the tests had smooth, firm surfaces, and those from tests 251 and 252 fractured with difficulty. Those from tests 254 and 255 were more brittle, though not easily broken. The surface of the briquets from tests 251, 252, and 254 was smooth and firm, whereas the surface of briquets from test 255 crumbled easily. The cold briquets of tests 251, 252, and 254 were excellent, had smooth, firm surfaces, broke without crumbling, and the fractured surfaces were smooth and firm. The cold briquets of test 255 were rather brittle and fractured easily, and the surface of fractures crumbled easily.

The entire shipment of coal was made into briquets and delivered to the U. S. S. *Connecticut* for trial test under marine boilers. The test on the *Connecticut* was conducted in December, 1907, on a run from New York Harbor to Hampton Roads, Va.

Briquetting tests.

	Test 251.	Test 252.	Test 254.	Test 255.
Size as used:				
Over ¼ inch......per cent..	1.3	0.1	0.0	0.0
1/10 inch to ¼ inch......do....	3.4	6.3	9.4	7.4
1/20 inch to 1/10 inch......do....	13.7	22.6	24.2	23.5
1/40 inch to 1/20 inch......do....	27.2	32.3	28.0	28.3
Through 1/40 inch......do....	54.4	38.7	38.4	40.8
Details of manufacture:				
Machine used......	English.	Renfrow No. 2.	Renfrow No. 2.	Renfrow No. 2.
Briquetting temperature......°F..	192	200	204	205
Binder—				
Kind......	W. G. P.	W. G. P.	W. G. P.	W. G. P.
Laboratory No......	5458	5458	5563	5563
Amount......per cent..	6	6	8	6
Weight of—				
Fuel briquetted......pounds..	138,101	181,600	2,000	2,000
Briquet, average......do....	3.27	0.633	0.581	0.595
Moisture in briquet mixture......per cent..	7.62	3.99	......	......
Drop test (1-inch screen):				
Held......do....	74.0	66.5	65.0	46.0
Passed......do....	26.0	33.5	35.0	54.0
Tumbler test (1-inch screen):				
Held......do....	79.0	69.0	71.0	60.5
Passed......do....	21.0	31.0	29.0	39.5
Fines through 10-mesh sieve......do....	93.4	95.5	95.2	95.5
Weather test:				
Time exposed......days..	171	178	161	161
Condition......	A	A	A	B
Absorption test:				
Time immersed......days..	30	21	21	21
Water absorbed......per cent..	15.38	14.02	15.46	16.62
Average for first four days......do....	2.04	2.74	2.78	3.29
Specific gravity (apparent)......	1.097	1.108	1.101	1.086

Chemical analyses of coal and briquets.

	Raw fuel.	Test 251.	Test 252.	Test 254.	Test 255.
Laboratory No......	5333	5466	5454	5455	5457
Proximate:					
Moisture......per cent..	17.68	18.52	19.73	19.70	19.88
Fixed carbon......do....	74.19	72.79	72.65	73.08	73.22
Ash......do....	6.13	6.24	5.98	5.62	5.50
Sulphur......do....	.59	.63	.61	.50	.58
Ultimate:					
Hydrogen......do....	4.47	4.37	4.51	4.65	4.22
Carbon......do....	84.54	82.66	84.86	85.93	84.81
Nitrogen......do....	.89	.86	.88	.99	.90
Oxygen......do....	3.24	5.06	3.05	2.21	3.90

Extraction analyses.

	Pitches.		Fuel, J-2.	Briquets.			
				Test 251.	Test 252.	Test 254.	Test 255.
Laboratory No......	5458	5563	5333	5466	5454	5455	5457
Air-drying loss......per cent..	......	......	1.20	1.80	1.10	1.10	0.90
Extracted by CS_2 (as received).do....	92.92	90.33	0.56	5.83	7.75	7.65	5.87
Pitch in briquet by analysis....do....	......	......	......	5.71	5.62	7.90	5.92
Heat value......B. t. u..	16,893	16,718	14,632	14,549	14,726	14,794	14,796

VIRGINIA—JAMESTOWN NO. 14.

The sample designated as Jamestown No. 14 consisted of a car of Virginia semianthracite culm from a mine working the Big Vein, Merrimac, Montgomery County, Va., on the Virginia Anthracite Railway.

The sample was tested at the Norfolk plant.

As received, the sample was very wet, and serious difficulty was experienced in crushing it with the Williams mill because of its tendency to pack and stop the mill. About 11 tons of briquets was made, however, and these were stronger than necessary when made with 8 per cent of pitch binder, but were rather weak with 6 per cent; 7 per cent would probably make a satisfactory briquet. When tested in a kitchen range, the briquets did not burn with satisfactory results, but after being broken into three or four pieces a better fire was obtained than with a good grade of anthracite coal of egg size. The briquets made a satisfactory fuel for an open-grate fire and for large heating stoves. They had a peculiar property of ''banking,'' owing to the high percentage of ash in them (22.5 per cent), and a fire could be kept over night with them, even in a small kitchen range.

Briquetting test.

	Test 291.		Test 291.
Size as used:		Drop test (1-inch screen):	
Over $\frac{1}{4}$ inch per cent	0.0	Held per cent	16.0
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch do	11.9	Passed do	84.0
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch do	32.8	Tumbler test (1-inch screen):	
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch do	24.3	Held do	28.0
Through $\frac{1}{40}$ inch do	31.0	Passed do	72.0
Details of manufacture:			
Machine used	Renfrow No. 2	Fines through 10-mesh sieve, per cent	94.1
Briquetting temperature °F	187	Weather test:	
Binder—		Time exposed days	102
Kind used	W. G. P.	Condition	B
Laboratory No.	5940	Absorption test:	
Amount per cent	6	Time immersed days	31
Weight of—		Water absorbed per cent	12.76
Fuel briquetted pounds	22,000	Average for first 4 days do	1.63
Briquet, average do	0.746	Specific gravity (apparent)	1.299
Moisture in briquet mixture, per cent	7.35		

Chemical analyses of culm from Merrimac, Va., and of briquets made.

	Raw fuel.	Test 291.	Pitch binder.
Laboratory No.	5938	6114	5940
Proximate:			
Moisture per cent	2.05	2.07	
Volatile matter do	6.58	9.93	
Fixed carbon do	58.22	65.48	
Ash do	33.15	22.52	
Sulphur do	.46	.52	
Ultimate:			
Hydrogen do	2.43	3.04	
Carbon do	59.18	68.13	
Nitrogen do	.65	1.00	
Oxygen do	3.43	4.30	

Extraction analyses.

	Pitch.	Fuel.	Briquets.
		J-14.	Test 291.
Laboratory No	5940	5938	6114
Air-drying loss ... per cent		1.60	1.10
Extracted by CS_2 (as received) ... do	96.60	.06	5.19
Pitch in briquet by analyses ... do			5.32
Heat value ... B. t. u	16,780	9,688	11,598

WASHINGTON NO. 2.

Bituminous lump coal from Roslyn, Kittitas County, on the Northern Pacific Railway, was designated Washington No. 2, and a part (12,000 pounds) of the sample was used in briquetting test 125.

Steaming test 412 was made of briquets from this briquetting test.

Briquetting tests.

	Test 125.	Test 125.
Size as shipped	Lump.	Lump.
Size as used:		
Over $\frac{1}{4}$ inch ... per cent	2.4	2.4
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch ... do	11.0	11.0
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch ... do	19.6	19.6
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch ... do	26.2	26.2
Through $\frac{1}{40}$ inch ... do	40.8	40.8
Details of manufacture:		
Machine used	English.	Renfrow No. 1.
Binder—		
Kind used	W. G. P.	W. G. P.
Laboratory No	3410	3410
Amount used ... per cent	6.5 and 7	6, 6.5, 7
Weight of—		
Fuel briquetted ... pounds	(a)	(a)
Briquet, average ... do	3.24	0.46
Heat value per pound:		
Fuel as received ... B. t. u	12,586	
Briquets ... do	12,890	
Binder ... do	16,478	
Drop test (1-inch screen):		
Held by ... per cent	[b] 87.4	
Passed ... do	12.6	
Weather test:		
Time exposed ... days	214	214
Condition	5.5 per cent C, others B.	6.5 per cent C, 7 and 7.5 per cent B.

[a] Total weight of both English and Renfrow briquets made was 12,000 pounds.
[b] Drop test made with 6 per cent briquets.

Chemical analyses of coal and briquets.

	Fuel.	Briquets.		Fuel.	Briquets.
		Test 125.			Test 125.
Laboratory No	3098		Ultimate:		
Proximate:			Hydrogen ... per cent	4.96	4.86
Moisture ... per cent	3.16	2.66	Carbon ... do	71.62	73.02
Volatile matter ... do	36.49	37.39	Nitrogen ... do	1.28	1.48
Fixed carbon ... do	48.09	48.89	Oxygen ... do	9.09	8.88
Ash ... do	12.26	11.06			
Sulphur ... do	.38	.39			

Extraction analyses.

	Pitch.	Fuel.	Briquets, test 125.
		Wash No. 2.	
Laboratory No	3410	3098	....
Air-drying loss ... per cent	....	1.30	0.20
Extract by CS_2 (as received) ... do	79.98	1.24	6.89
Pitch in briquet by analysis ... do	....	....	7.19
Heat value ... B. t. u	16,478	12,586	12,890

WEST VIRGINIA NO. 3.[a]

A sample of run-of-mine bituminous coal from near Morgantown, Monongalia County, on the Morgantown & Kingwood Railroad, was designated West Virginia No. 3, and a part of the sample was subjected to briquetting tests on the laboratory press at the St. Louis plant.

A test was made with this coal in the laboratory to determine whether it was possible, under a certain pressure and temperature, to make a briquet without any binder. A briquet was obtained, which, although not perfectly satisfactory, indicated that under certain conditions, with the right pressure and temperature, briquets could be made with this coal without any binder whatever, but it is doubtful whether a briquet made of bituminous coal in this manner would possess satisfactory strength to be of commercial value.

Chemical analysis.

	Car sample.		Car sample.
Laboratory No	1252	Ultimate:	
Proximate:		Hydrogen ... per cent	4.85
Air-drying loss ... per cent	1.30	Carbon ... do	76.89
Moisture ... do	2.29	Nitrogen ... do	1.45
Volatile ... do	29.86	Oxygen ... do	5.26
Fixed carbon ... do	57.62	Heat value ... B. t. u	13,558
Ash ... do	10.23		
Sulphur ... do	1.06		

WEST VIRGINIA NO. 6.

A sample of run-of-mine semibituminous coal from Rush Run, Fayette County, on the Chesapeake & Ohio Railroad, was designated West Virginia No. 6, and a part of the sample was subjected to briquetting tests on both the English and the American machines at the St. Louis plant.

The first test made of this coal was with 5 per cent of the glossy, home-made pitch Y. The pressure used was the limit that could be obtained on the English machine, and the resultant briquets were hard, clean, and strong, and had a sharp, glossy fracture. They were in every way equal to the best briquets made on this machine. They weighed on an average 6.12 pounds each. On account of the excellent quality of the briquets with 5 per cent of pitch, another ton was briquetted with only 3 per cent of pitch Y. Extreme pressure was applied, and the resultant briquets were unusually smooth and glossy, but not quite strong enough. They crumbled instead of cracking clean under the blows of a hammer. The briquets containing 5 per cent of pitch, when broken, made little or no waste, and had a clean fracture.

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[a] See description of tests on pp. 62–63.

On the American machine the mixture containing 5 per cent of pitch Y made very glossy and solid eggettes, which were strong and would stand much rough handling. One surprising quality of these briquets was that when tested in the cook stove they burned with little or no caking, although the coal itself is a very good coking coal. The briquets, when exposed to the weather, were little affected and did not disintegrate appreciably. In burning they held together until entirely consumed.

This coal was also tested with the Hoffman patent binder, and the resultant eggettes were also of good quality, being hard, glossy, and clean; but in burning they caked more than those with 5 per cent of pitch.

Chemical analysis.

	Car sample.		Car sample.
Laboratory No.	1390	Ultimate:	
Proximate:		Hydrogen........per cent..	4.66
Air-drying loss........per cent..	.90	Carbon........do....	84.16
Moisture........do....	1.53	Nitrogen........do....	1.71
Volatile matter........do....	21.54	Oxygen........do....	3.68
Fixed carbon........do....	71.88	Heat value........B. t. u..	14,807
Ash........do....	5.05		
Sulphur........do....	.65		

WEST VIRGINIA—JAMESTOWN NO. 3.

The sample designated Jamestown No. 3 consisted of two cars of semibituminous run-of-mine coal from a mine working the "Thin Vein" Pocahontas bed, Davy, McDowell County, W. Va., on the Norfolk & Western Railway.

Excellent briquets were made on the English machine with this coal and 6 per cent of binder (Lab. No. 5458), and good briquets were made on the Renfrow No. 2 machine with the same coal and binder. The briquets made on the American machine (test 257) with 7 per cent of binder (Lab. No. 5563) also had a good appearance, but were not so strong as those from the other two tests.

Briquets from test 253, while warm, had a smooth surface, metallic luster, and no cracks, but were easily crushed in the hand; when cold, however, they had a fine metallic ring when struck, a firm, fine-grained surface, and broke with difficulty, with a firm, fine-grained, lustrous fracture.

Briquets from test 256, while warm, had a smooth surface, were plastic, and broke with a rough fractured surface. When cold these briquets had rough ends, broke without slacking, and had a smooth and glossy fracture.

Briquets from test 257 hardened at a rather high temperature and fractured with difficulty. When cold these briquets had a firm, smooth surface, were somewhat brittle, and formed some slack when broken.

Briquetting tests.

	Test 253.	Test 256.	Test 257.
Size as used:			
Over $\frac{1}{4}$ inch ... per cent.	0.8	...	0.1
$\frac{1}{10}$ to $\frac{1}{4}$ inch ... do.	3.5	...	6.1
$\frac{1}{20}$ to $\frac{1}{10}$ inch ... do.	14.7	...	28.8
$\frac{1}{40}$ to $\frac{1}{20}$ inch ... do.	27.0	...	29.5
Through $\frac{1}{40}$ inch ... do.	54.0	...	35.5
Details of manufacture:			
Machine used	English.	Renfrow No. 2.	Renfrow No. 2.
Briquetting temperature ... ° F.	202	204	205
Binder—			
Kind	W. G. P.	W. G. P.	W. G. P.
Laboratory No	5458	5458	5563
Amount ... per cent.	6	6	7
Weight of—			
Fuel briquetted ... pounds.	24,600	12,000	10,000
Briquet, average ... do.	3.53	0.617	0.588
Moisture in briquet mixture ... per cent.	6.09	2.71	4.91
Drop test (1-inch screen):			
Held ... do.	76.4	62.0	37.5
Passed ... do.	23.6	38.0	62.5
Tumbler test (1-inch screen):			
Held ... do.	71.8	58.5	47.5
Passed ... do.	28.2	41.5	52.5
Fines through 10-mesh sieve ... do.	89.7	95.0	95.0
Weather test:			
Time exposed ... days.	162	154	154
Condition	A	B	B
Absorption test:			
Time immersed ... days.	30	21	21
Water absorbed ... per cent.	12.02	14.46	15.79
Average for first 4 days ... do.	2.04	2.71	3.12
Specific gravity (apparent)	1.143	1.121	1.101

Chemical analyses of coal and briquets.

	Raw fuel.	Test 253.	Test 256.	Test 257.
Laboratory No	5459	5477	5478	5743
Proximate:				
Moisture ... per cent.	1.52	1.86	1.69	1.06
Volatile matter ... do.	15.01	17.26	18.40	17.30
Fixed carbon ... do.	76.19	75.54	74.26	76.13
Ash ... do.	7.28	5.34	5.65	5.51
Sulphur ... do.	.62.	.66	.64	.65
Ultimate:				
Hydrogen ... do.	4.45	4.45	4.50	4.63
Carbon ... do.	83.78	85.46	85.31	86.06
Nitrogen ... do.	1.14	1.09	1.11	1.10
Oxygen ... do.	2.61	2.89	2.68	1.98

Extraction analyses.

	Pitches.		Fuel, J-3.	Briquets.		
				Test 253.	Test 256.	Test 257.
Laboratory No	5458	5563	5459	5477	5478	5743
Air-drying loss ... per cent.	...	...	0.90	1.30	1.20	0.70
Extracted by CS_2 (as received) ... do.	92.92	90.33	0.47	5.03	5.28	5.86
Pitch in briquet, by analysis ... do.	...	...	...	4.93	5.20	6.00
Heat value ... B. t. u.	16,893	16,718	14,443	14,828	14,728	14,836

WEST VIRGINIA—JAMESTOWN NO. 5.

The sample designated Jamestown No. 5 consisted of two cars of semibituminous run-of-mine coal from a mine working the Sewell bed, 1 mile east of Sewell, Fayette County, W. Va., on the Chesapeake & Ohio Railway.

Of the two tests made on this coal, the briquets of test 258 were better than those of test 259. The warm briquets of test 258 had smooth surfaces and were difficult to fracture. The cold briquets were very hard and brittle and formed some slack when broken. The warm briquets from test 259 had smooth surfaces, were very plastic, and high in moisture; the cold briquets had a very hard, firm surface, and fractured without slacking.

Briquetting tests.

	Test 258.	Test 259.
Size as used:		
Over $\frac{1}{4}$ inch........per cent..	0.1	....
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch........do....	6.5	....
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch........do....	27.0	....
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch........do....	31.0	....
Through $\frac{1}{40}$ inch........do....	35.3	....
Details of manufacture:		
Machine used........	Renfrow No. 2.	Renfrow No. 2.
Briquetting temperature........°F..	199	200
Binder—		
Kind........	W. G. P.	W. G. P.
Laboratory No........	5563	5458
Amount........per cent..	7	7
Weight of—		
Fuel briquetted........pounds..	136,000	2,000
Briquet, average........do....	0.568	0.588
Moisture in briquet mixture........per cent..	6.14	....
Drop test (1-inch screen):		
Held........do....	70.0	48.5
Passed........do....	30.0	51.5
Tumbler test (1-inch screen):		
Held........do....	71.5	67.5
Passed........do....	28.5	32.5
Fines through 10-mesh sieve........do....	95.5	95.2
Weather test:		
Time exposed........days..	154	154
Condition........	A	A
Absorption test:		
Time immersed........days..	21	21
Water absorbed........per cent..	14.99	15.28
Average for first 4 days........do....	2.52	2.62
Specific gravity (apparent)........	1.092	1.103

Chemical analyses of coal and briquets.

	Raw fuel.	Test 258.
Laboratory No........	5453	5744
Proximate:		
Moisture........per cent..	3.37	1.32
Volatile matter........do....	21.80	24.97
Fixed carbon........do....	70.74	67.91
Ash........do....	4.09	5.80
Sulphur........do....	.58	.63
Ultimate:		
Hydrogen........do....	4.85	4.81
Carbon........do....	85.06	83.88
Nitrogen........do....	1.39	1.16
Oxygen........do....	3.87	3.63

Extraction analyses.

	Pitches.		Fuel, J-5.	Briquets, test 258.
Laboratory No	5563	5458	5453	5744
Air-drying loss per cent			2.60	0.90
Extracted by CS_2 (as received) do	90.33	92.92	0.51	6.62
Pitch in briquet by analysis do				6.81
Heat value B. t. u.	16,718	16,893	14,522	14,677

WEST VIRGINIA—JAMESTOWN NO. 6.

The sample designated Jamestown No. 6 consisted of two cars of semibituminous run-of-mine coal from a mine working the Sewell bed, Redstar Fayette County, W. Va., on the Chesapeake & Ohio Railway.

The briquets made from this coal were excellent in their physical characteristics, and when warm had smooth surfaces, sharp edges, and were sufficiently strong to be loaded on cars direct from the briquetting machine. When cold, these briquets were hard and firm, but somewhat brittle on the edges.

Briquetting test.

	Test 260.		Test 260.
Size as used:		Drop test (1-inch screen).	
Over ¼ inch per cent	0.8	Held per cent	80.2
1/10 inch to ¼ inch do	3.1	Passed do	19.8
1/20 inch to 1/10 inch do	11.2	Tumbler test (1-inch screen):	
1/40 inch to 1/20 inch do	26.3	Held do	77.4
Through 1/40 inch do	54.8	Passed do	22.6
Details of manufacture:			
Machine used	English.	Fines through 10-mesh sieve, per cent	88.5
Briquetting temperature °F	203	Weather test:	
Binder—		Time exposed days	135
Kind	W. G. P.	Condition	A
Laboratory No	5563	Absorption test:	
Amount per cent	6	Time immersed days	35
Weight of—		Water absorbed per cent	13.19
Fuel briquetted pounds	41,400	Average for first 4 days do	2.24
Briquet, average do	3.52	Specific gravity (apparent)	1.117
Moisture in briquet mixture per cent	5.47		

Chemical analyses of coal and briquets.

	Raw fuel.	Test 260.		Raw fuel.	Test 260.
Laboratory No	5489	5558	Ultimate:		
Proximate:			Hydrogen per cent	4.74	4.96
Moisture per cent	2.09	2.15	Carbon do	81.31	85.20
Volatile matter do	19.39	21.87	Nitrogen do	1.36	1.56
Fixed carbon do	74.63	71.13	Oxygen do	7.71	2.49
Ash do	3.89	4.85			
Sulphur do	.89	.81			

Extraction analyses.

	Pitch.	Fuel, J-6.	Briquets, test 260.
Laboratory No	5563	5489	5558
Air-drying loss per cent		1.50	1.50
Extracted by CS_2 (as received) do	90.33	0.36	5.32
Pitch in briquet by analysis do			5.51
Heat value B. t. u.	16,718	14,783	14,715

WEST VIRGINIA—JAMESTOWN NO. 7.

The sample designated Jamestown No. 7 consisted of three cars of semibituminous run-of-mine coal from a mine working the Sewell bed, Derryhale, Fayette County, W. Va.; on the Chesapeake & Ohio Railway.

The briquets made on the Renfrow No. 2 machine from this coal with 7 per cent of binder (Lab. No. 5563) stood the cohesion tests better than those made on the English machine with 6 per cent of the same binder. Both were excellent briquets, gave a fine metallic ring when struck, had smooth, firm surfaces, broke with difficulty, and had firm and glossy fractures.

Briquetting tests.

		Test 261.	Test 262.
Size as used:			
Over $\frac{1}{4}$ inch	per cent	3.0	0.3
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch	do	6.9	6.0
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch	do	10.8	25.1
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch	do	22.4	29.3
Through $\frac{1}{40}$ inch	do	56.9	39.3
Details of manufacture:			
Machine used		English.	Renfrow No. 2.
Briquetting temperature	° F	198	193
Binder—			
Kind		W. G. P.	W. G. P.
Laboratory No		5563	5563
Amount	per cent	6	7
Weight of -			
Fuel briquetted	pounds	43,200	38,000
Briquet, average	do	3.53	0.617
Moisture in briquet mixture	per cent	5.48	4.71
Drop test (1-inch screen):			
Held	do	69.3	71.0
Passed	do	30.7	29.0
Tumbler test (1-inch screen):			
Held	do	74.0	80.5
Passed	do	26.0	19.5
Fines through 10-mesh sieve	do	88.6	95.2
Weather test:			
Time exposed	days	132	132
Condition		A	B
Absorption test:			
Time immersed	days	35	11
Water absorbed	per cent	11.09	12.21
Average for first 4 days	do	2.14	2.85
Specific gravity (apparent)		1.139	1.029

Chemical analyses of coal and briquets.

		Raw fuel.	Test 261.	Test 262.
Laboratory No		5501	5583	5559
Proximate:				
Moisture	per cent	2.00	2.70	0.93
Volatile matter	do	17.57	20.28	18.52
Fixed carbon	do	74.10	72.74	74.65
Ash	do	6.33	4.28	5.90
Sulphur	do	.91	.81	.81
Ultimate:				
Hydrogen	do	4.59	4.77	4.69
Carbon	do	83.03	86.07	84.46
Nitrogen	do	1.31	1.49	1.51
Oxygen	do	3.68	2.44	2.56

Extraction analyses.

	Pitch.	Fuel, J-7.	Briquets.	
			Test 261.	Test 262.
Laboratory No.	5563	5501	5583	5559
Air-drying loss per cent.		1.40	2.10	0.30
Extract by CS_2 (as received) do.	90.33	.40	4.99	6.56
Pitch in briquet by analysis do.			5.12	6.85
Heat value B. t. u.	16,718	14,465	14,886	14,717

WEST VIRGINIA—JAMESTOWN NO. 8.

The sample designated Jamestown No. 8 consisted of two cars of semibituminous run-of-mine coal from a mine working the Quinnimont (Fire Creek) bed, Lawton, Fayette County, W. Va., on the Chesapeake & Ohio Railway.

This coal was briquetted with binders as follows: Tests 263, 264, and 270, with flour binder alone; test 271, with water-gas pitch alone; and the remaining tests, 265, 266, 267, 268, and 269, with various mixtures of flour and water-gas pitch.

All of the briquets made with flour alone disintegrated very rapidly on exposure to the weather, and one sample (from test 270) crumbled to slack when handled after being immersed in water for 24 hours. The briquets made with 1 per cent of flour binder were not strong enough to be satisfactory, but all of the other briquets made with flour alone or with a mixture of flour and water-gas pitch stood the cohesion tests better than the briquets that had only water-gas pitch for a binder. A comparison of tests 267, 268, and 269 with test 271 shows that in the first three tests the drop and tumbler percentages were higher than in the fourth test. All briquets containing any flour soon became covered with a green mold when stored in a damp place and lost strength, but those stored in a dry place developed no mold, and even after eight months were seemingly as good as when first made. In making briquets with flour alone, some difficulty was experienced from the briquets sticking to the dies of the press, but it is probable that when the conditions are better understood this trouble may be obviated. The briquets from test 268 were stronger than those from any other of the nine tests made of this coal, but those from test 269 were almost as strong. The briquets made with 7 per cent of water-gas pitch alone (test 271) were of excellent quality, but were somewhat sticky when hot, although they were loaded into the car direct from the machine with very little breakage. No samples were taken for sizing tests and chemical analyses from the briquets made in tests 263 to 270, inclusive, as all these tests were of preliminary nature.

Briquetting tests.

	Test No.				
	263.	264.	270.	265.	266.
Details of manufacture:					
Machine used	Renfrow No.2	English.	Renfrow No.2	English.	English.
Briquetting temperature, °F	198	201	....	201	....
Binder—					
Kind	Flour.	Flour.	Flour.	Flour. W. G. P.	Flour. W. G. P.
Laboratory No	6110	6110	6110	Flour 6110 W. G. P. 5939	Flour 6110 W. G. P. 5939
Amount.....per cent..	1.0	2.0	4	1 flour. 3 W. G. P.	2 flour. 2 W. G. P.
Weight of—					
Fuel briquetted...lbs..	500	500	500	500	500
Briquet, average ..do..	0.558	3.55	0.595	3.47	3.55
Moisture in briquet mixture, per cent	....	....	7.29	....	....
Drop test (1-inch screen):					
Held.........per cent..	65.5	60.2	79.5	60.2	76.1
Passed.........do....	34.5	39.8	20.5	39.8	23.9
Tumbler test (1-inch screen):					
Held.........do....	31.9	56.0	89.0	67.2	75.6
Passed.........do....	68.1	44.0	11.00	32.8	24.4
Fines through 10-mesh sieve.......per cent..	92.7	92.0	96.0	94.0	89.2
Weather test:					
Time exposed.......days..	132	132	132	132	132
Condition	E	E	E	C	D
Absorption test:					
Time immersed.....days..	8	9	1	8	4
Water absorbed.per cent..	5.94	9.76	10.60	9.31	10.29
Average for first four days.......per cent..	1.53	2.44	(a)	2.31	2.57
Specific gravity (apparent)....	1.222	1.184	1.079	1.168	1.157

	Test No.			
	267.	268.	269.	271.
Size as used:				
Over $\frac{1}{4}$ inch.........per cent..	....	....	....	0.0
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch.........do....	....	....	....	9.3
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch.........do....	....	....	....	35.5
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch.........do....	....	....	....	29.2
Through $\frac{1}{40}$ inch.........do....	....	....	....	28.0
Details of manufacture:				
Machine used	Renfrow No. 2	Renfrow No. 2	Renfrow No. 2	Renfrow No. 2
Briquetting temperature......°F..	....	....	....	196
Binder—				
Kind	Flour. W. G. P.	Flour. W. G. P.	Flour. W. G. P.	W. G. P.
Laboratory No	Flour 6110 W. G. P. 5941	Flour 6110 W. G. P. 5941	Flour 6110 W. G. P. 5941	5941
Amount.........per cent..	2 flour. 2 W. G. P.	2 flour. 3 W. G. P.	2 flour. 2 W. G. P.	7
Weight of—				
Fuel briquetted......pounds..	500	500	500	81,250
Briquet, average.........do....	0.562	0.588	0.562	0.633
Moisture in briquet mixture. per cent..	....	6.29	5.72	5.21
Drop test (1-inch screen):				
Held.........do....	84.0	87.0	84.5	46.5
Passed.........do....	16.0	13.0	15.5	53.5
Tumbler test (1-inch screen):				
Held.........per cent..	81.0	91.0	88.0	58.0
Passed.........do....	19.0	9.0	12.0	42.0
Fines through 10-mesh sieve.do....	95.7	96.7	97.0	95.5
Weather test:				
Time exposed.........days..	132	132	132	127
Condition	E	B	C	A
Absorption test:				
Time immersed.........days..	4	5	4	12
Water absorbed.........per cent..	11.47	8.09	16.56	15.31
Average for first 4 days.......do....	2.87	2.00	4.14	3.56
Specific gravity (apparent)	1.150	1.196	1.087	1.100

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[a] Sample crumbled after one day's immersion.

Chemical analyses of semibituminous coal from Lawton, W. Va., and of flour binder.

	Raw fuel.	Test 271.	Flour binder.
Laboratory No	5575	5713	6110
Proximate:			
Moisture ... per cent	2.80	3.28	13.30
Volatile matter ... do	17.10	18.50	72.30
Fixed carbon ... do	74.80	73.44	13.50
Ash ... do	5.30	4.78	.90
Sulphur ... do	.86	.84	.10
Ultimate:			
Hydrogen ... do	4.75	4.75	....
Carbon ... do	85.07	85.05	....
Nitrogen ... do	1.44	1.11	....
Oxygen ... do	2.41	3.28	....

Extraction analyses.

	Binders.			Fuel, J-8.	Briquets, test 271.
	Pitch.	Flour.	Pitch.		
Laboratory No	5941	6110	5939	5575	5713
Air-drying loss ... per cent	....	....	....	2.20	2.90
Extracted by CS_2 (as received) ... do	98.44	....	98.13	0.52	4.80
Pitch in briquets by analysis ... do	....	....	....	....	4.38
Heat value ... B. t. u.	16,978	6,998	16,781	14,701	14,584

WEST VIRGINIA—JAMESTOWN NO. 9.

The sample designated as Jamestown No. 9 consisted of two cars of semibituminous run-of-mine coal from a mine working the Sewell bed, Winona, Fayette County, W. Va., on the Chesapeake & Ohio Railway.

The coal was briquetted with three different kinds of pitch binder. The briquets from test 274 made with water-gas pitch (Lab. No. 5939) were the strongest of the three. All three tests made excellent briquets, which gave a good metallic ring when knocked together, had smooth, hard surfaces, were broken with difficulty, and had firm and glossy fractured surfaces. No analyses of briquets from tests 273 and 274 were made.

Briquetting tests.

	Test No.		
	272.	273.	274.
Size as used:			
Over ¼ inch ... per cent	0.0	....	....
1/10 inch to ¼ inch ... do	7.9	....	....
1/20 inch to 1/10 inch ... do	22.9	....	....
1/40 inch to 1/20 inch ... do	30.5	....	....
Through 1/40 inch ... do	37.1	....	....
Details of manufacture:			
Machine used	Renfrow No. 2	Renfrow No. 2	Renfrow No. 2
Briquetting temperature ... °F	195	198	198
Binder—			
Kind	W. G. P.	W. G. P.	W. G. P.
Laboratory No	5941	5563	5939
Amount ... per cent	7	7	7
Weight of—			
Fuel briquetted ... pounds	46,000	2,000	2,000
Briquet, average ... do	0.625	0.602	0.610

Briquetting tests—Continued.

	Test No.		
	272.	273.	274.
Moisture in briquet mixture.................per cent..	5.65	....	....
Drop test (1-inch screen):			
Held.......................................do....	57.5	71.0	73.0
Passed.....................................do....	42.5	29.0	27.0
Tumbler test (1-inch screen):			
Held.......................................do....	64.0	77.0	83.5
Passed.....................................do....	36.0	23.0	16.5
Fines through 10-mesh sieve................do....	95.1	96.7	96.6
Weather test:			
Time exposed.............................days..	125	52	125
Condition..	A	A	A
Absorption test:			
Time immersed............................days..	12	21	13
Water absorbed.......................per cent..	16.66	13.02	13.14
Average for first 4 days....................do....	3.49	2.75	2.79
Specific gravity (apparent)..............................	1.072	1.118	1.117

Chemical analyses of coal and briquets.

	Raw fuel.	Test 272.
Laboratory No..	5709	5745
Proximate:		
Moisture..per cent..	3.98	2.64
Volatile matter..do....	23.21	25.29
Fixed carbon...do....	67.41	67.61
Ash...do....	5.40	4.46
Sulphur...do....	.66	.65
Ultimate:		
Hydrogen..do....	5.01	5.00
Carbon..do....	82.85	84.57
Nitrogen..do....	1.40	1.14
Oxygen..do....	4.43	4.05

Extraction analyses.

	Pitches.			Fuel, J–9.	Briquets, test 272.
Laboratory No....................................	5941	5563	5939	5709	5745
Air-drying loss.........................per cent..	....	....	....	3.00	2.10
Extracted by CS_2 (as received)...............do....	98.44	90.33	98.13	0.69	4.77
Pitch in briquet by analysis.....................do....	....	....	....	....	4.18
Heat value.....................................B. t. u..	16,978	16,718	16,781	14,238	14,699

WEST VIRGINIA—JAMESTOWN NO. 10.

The sample designated as Jamestown No. 10 consisted of two cars of semibituminous run-of-mine coal from a mine working the Beckley bed, Stanaford, Raleigh County, W. Va., on the Chesapeake & Ohio Railway.

Test 275 gave satisfactory briquets with 6 per cent of water-gas pitch (Lab. No. 5941). The briquets had smooth, firm surfaces, sharp edges, were broken with difficulty, and had firm and glossy fracture surfaces.

Briquetting test.

	Test 275.		Test 275.
Size as used:		Drop test (1-inch screen):	
Over ¼ inch.....per cent..	4.5	Held.....per cent..	33.7
$\frac{1}{10}$ inch to ¼ inch.....do....	16.0	Passed.....do....	66.3
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch.....do....	28.8	Tumbler test (1-inch screen):	
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch.....do....	25.4	Held.....do....	55.0
Through $\frac{1}{40}$ inch.....do....	25.3	Passed.....do....	45.0
Details of manufacture:		Fines through 10-mesh sieve.do....	90.0
Machine used.....	English.	Weather test:	
Briquetting temperature.....°F..	182	Time exposed.....days..	120
Binder—		Condition.....	A
Kind.....	W. G. P.	Absorption test:	
Laboratory No.....	5941	Time immersed.....days..	21
Amount.....per cent..	6	Water absorbed.....per cent..	8.75
Weight of—		Average for first 4 days.....do....	2.07
Fuel briquetted.....pounds..	53,550	Specific gravity (apparent).....	1.205
Briquet, average.....do....	3.83		
Moisture in briquet mixture.per cent..	6.45		

Chemical analyses of coal and briquets.

	Raw fuel.	Test 275.
Laboratory No.....	5719	5746
Proximate:		
Moisture.....per cent..	2.14	3.83
Volatile matter.....do....	16.83	18.69
Fixed carbon.....do....	71.91	69.03
Ash.....do....	9.12	8.45
Sulphur.....do....	1.20	.91
Ultimate:		
Hydrogen.....do....	4.57	4.63
Carbon.....do....	81.34	81.32
Nitrogen.....do....	1.44	1.24
Oxygen.....do....	2.10	3.07

Extraction analyses.

	Pitch.	Fuel, J-10.	Briquets, test 275.
Laboratory No.....	5941	5719	5746
Air-drying loss.....per cent..	....	1.40	3.40
Extracted by CS_2 (as received).....do....	98.44	0.64	5.07
Pitch in briquet by analysis.....do....	....	....	4.53
Heat value.....B. t. u..	16,978	14,024	13,871

WEST VIRGINIA—JAMESTOWN NO. 11.

The sample designated as Jamestown No. 11 consisted of two cars of semibituminous run-of-mine coal from a mine working the Beckley bed, West Raleigh, Raleigh County, W. Va., on the Chesapeake & Ohio Railway.

In test 276 excellent briquets were made from this coal with 7 per cent of water-gas pitch (Lab. No. 5941).

In test 277 six tons of briquets was made on the English machine, with 3 per cent of flour for a binder. The briquets were strong even after standing for three months in a damp place, and briquets kept in a dry place for seven months appeared as good as when first made.

After exposure to the weather for six weeks in the wintertime, a sample of the briquets could be handled and was still serviceable, so that it would seem that flour may be considered a satisfactory binder when the briquets made from it are not exposed to the weather for more than two months.

In test 289, in order to compare flour and pitch binders, 6 tons of this coal was briquetted with 6 per cent of water-gas pitch (Lab. No. 5940); an excellent briquet was obtained. A comparison of the briquets from this test with those made with flour binder (test No. 277) shows that the flour briquets were stronger as indicated by physical tests but did not resist the effects of weathering as well as the pitch briquets.

In test 290 a mixture of 50 per cent of Jamestown No. 11 and 50 per cent of anthracite coal (buckwheat size), designated as Jamestown No. 18, was made to determine whether fine anthracite could be improved by briquetting with a bituminous coal. A very satisfactory briquet was obtained which had a firm, smooth surface, was hard to break, and had firm and glossy fracture surfaces.

Briquetting tests.

	Test 276.	Test 277.	Test 289.	Test 290.[a]
Size as used:				
Over $\frac{1}{4}$ inch ... per cent	0.1	...	0.4	5.7
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch ... do	7.4	...	4.2	17.2
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch ... do	29.9	...	23.2	19.6
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch ... do	27.7	...	39.6	18.9
Through $\frac{1}{40}$ inch ... do	34.9	11.41	32.6	38.6
Details of manufacture:				
Machine used	Renfrow No. 2.	English.	English.	English.
Briquetting temperature ... °F	190	185	...	191
Binder—				
Kind	W. G. P.	Flour.	W. G. P.	W. G. P.
Laboratory No.	5941	6110	5940	5940
Amount ... per cent	7	3	6	6
Weight of—				
Fuel briquetted ... pounds	42,000	12,000	12,750	12,350
Briquet, average ... do	0.610	3.78	3.77	4.15
Moisture in briquet mixture ... per cent	4.60	11.41	10.10	8.48
Drop test (1-inch screen):				
Held ... do	70.0	77.2	68.2	68.3
Passed ... do	30.0	22.8	31.8	31.7
Tumbler test (1-inch screen):				
Held ... do	77.5	60.7	72.0	78.5
Passed ... do	22.5	39.3	28.0	21.5
Fines through 10-mesh sieve ... do	94.0	88.3	88.2	87.5
Weather test:				
Time exposed ... days	120	120	102	102
Condition	A	D	A	A
Absorption test:				
Time immersed ... days	9	5	31	31
Water absorbed ... per cent	13.45	4.43	9.82	9.85
Average for first 4 days ... do	3.25	1.05	1.21	1.31
Specific gravity (apparent)	1.117	1.239	1.161	1.247

[a] Jamestown No. 11, 50 per cent; Jamestown No. 18, 50 per cent.

Chemical analyses of coal and briquets.

	Raw fuel.	Test 276.	Test 277.	Test 289.	Test 290.
Laboratory No.	5718	5756	6111	6112	6113
Proximate:					
Air-drying loss per cent	1.50	2.30	3.20	0.80	2.20
Moisture do.	2.15	2.73	3.83	1.61	3.42
Volatile matter do.	15.06	18.27	15.77	20.30	13.03
Fixed carbon do.	75.46	73.56	74.50	71.98	75.93
Ash do.	7.33	5.44	5.90	6.11	7.62
Sulphur do.	.90	.66	.69	.79	.63
Ultimate:					
Hydrogen do.	4.58	4.54	4.13	4.00	3.50
Carbon do.	84.09	85.15	82.59	82.58	83.01
Nitrogen do.	1.58	1.36	.88	1.47	1.50
Oxygen do.	1.34	2.68	5.55	4.94	3.45
Extract by CS_2 (as received) do.	.59	5.21		4.63	5.25
Pitch in briquet by analysis do.		4.72		4.21	5.12
Heat value B. t. u.	14,391	14,630	14,186	14,584	13,921

WEST VIRGINIA—JAMESTOWN NO. 12.

The sample designated Jamestown No. 12 consisted of one car of semibituminous coal from a mine working Pocahontas No. 3 bed, Switchback, McDowell County, W. Va., on the Norfolk & Western Railway.

This coal was briquetted first with 6 per cent of water-gas pitch (Lab. No. 5941), and such excellent briquets were obtained that test 279 was made to see whether 5 per cent of the same binder would make a satisfactory briquet. The briquet with 5 per cent of pitch was found to be better than that containing 6 per cent. Both tests made excellent briquets, which had firm, smooth surfaces, were broken with difficulty, and had firm, close-grained, and shiny fracture surfaces.

Briquetting tests.

	Test 278.	Test 279.
Size as used:		
Over ¼ inch per cent	5.6	5.6
1/10 inch to ¼ inch do.	18.1	18.1
1/20 inch to 1/10 inch do.	33.8	33.8
1/40 inch to 1/20 inch do.	23.2	23.2
Through 1/40 inch do.	19.3	19.3
Details of manufacture:		
Machine used	Renfrow No. 2.	Renfrow No. 2.
Briquetting temperature ° F.	195	194
Binder—		
Kind	W. G. P.	W. G. P.
Laboratory No.	5941	5941
Amount per cent	6	5
Weight of—		
Fuel briquetted pounds	38,000	16,000
Briquets, average do.	0.676	0.709
Moisture in briquet mixture per cent	5.03	
Drop test (1-inch screen):		
Held do.	59.0	66.5
Passed do.	41.0	33.5
Tumbler test (1-inch screen):		
Held do.	72.0	78.5
Passed do.	28.0	21.5
Fines through 10-mesh sieve do.	90.9	93.2
Weather test:		
Time exposed days	137	137
Condition	A	A
Absorption test:		
Time immersed days	5	4
Water absorbed per cent	11.73	12.18
Average for first 4 days do.	2.91	3.05
Specific gravity (apparent)	1.251	1.248

Chemical analyses of coal and briquets.

	Raw fuel.[a]	Test 278.
Laboratory No	5706	5856
Proximate:		
Moisture, per cent	3.01	1.71
Volatile matter, do	15.94	13.96
Fixed carbon, do	76.31	68.36
Ash, do	4.74	15.97
Sulphur, do	.44	.42
Ultimate:		
Hydrogen, do		3.87
Carbon, do		74.41
Nitrogen, do		.78
Oxygen, do		4.26

[a] Analysis of mine sample; no car sample taken.

Extraction analyses.

	Pitch.	Fuel, J–12.	Briquets, test 278.
Laboratory No	5941	5706	5856
Air-drying loss, per cent		2.40	1.10
Extracted by CS_2 (as received), do	98.44	0.17	5.74
Pitch in briquet by analysis, do			5.67
Heat value, B. t. u	16,978	14,715	12,938

WEST VIRGINIA—JAMESTOWN NO. 13.

The sample designated Jamestown No. 13 consisted of three cars of semibituminous run-of-mine coal from a mine working the Pocahontas No. 3 bed, Ennis, McDowell County, W. Va., on the Norfolk & Western Railway.

This coal was briquetted on both the English and the Renfrow No. 2 machines. The briquets were shipped from the plant for locomotive tests without any samples being retained, so no physical tests could be made of the briquets. In appearance, just after making, the briquets made on the English machine were very satisfactory and had firm, smooth surfaces.

The locomotive steaming tests are briefly described under the heading "Locomotive-boiler Tests ."

Briquetting tests.

	Test 286.	Test 287.
Details of manufacture:		
Machine used	English.	Renfrow No. 2.
Binder—		
Kind	W. G. P.	W. G. P.
Laboratory No	5940	5940
Amount, per cent	6	6
Weight of fuel briquetted, pounds	82,950	160,000

Chemical analyses of coal and briquets.

	Raw fuel.	Test 286.
Laboratory No.	5829	5948
Proximate:		
Moisture ... per cent.	3.67	3.10
Volatile matter ... do.	15.09	17.08
Fixed carbon ... do.	74.69	73.11
Ash ... do.	6.55	6.71
Sulphur ... do.	.46	.52
Ultimate:		
Hydrogen ... do.	4.06	4.16
Carbon ... do.	84.84	83.33
Nitrogen ... do.	.98	1.00
Oxygen ... do.	2.84	4.05

Extraction analyses.

	Pitch.	Fuel, J. 13.	Briquets, test 286.
Laboratory No.	5940	5829	5948
Air-drying loss ... per cent.	....	2.80	2.60
Extracted by CS_2 (as received) ... do.	96.60	.34	5.17
Pitch in briquet by analysis ... do.	....	....	5.02
Heat value ... B. t. u.	16,780	14,290	14,299

WEST VIRGINIA—JAMESTOWN NO. 15.

The sample designated Jamestown No. 15 consisted of several cars of semibituminous run-of-mine coal from a mine working the Sewell bed, Minden, Fayette County, W. Va., on the Chesapeake & Ohio Railway, and was tested at the Norfolk plant.

In test 280, owing to the presence of an excessive amount of moisture in this coal, it was difficult to make satisfactory briquets on the English machine. Water cracks formed, and the briquets had a porous surface which was easily rubbed off. They were easily broken, forming considerable slack. As the flowing point of the binder used in this test was 194° F., the briquetting temperature of 187° F. was not high enough to soften the pitch sufficiently to obtain the best results.

In test 281 the briquets made on the Renfrow No. 2 machine were probably stronger than those of test 280, made on the English machine, but the sample saved for the physical tests was mislaid, making it impossible to apply tests. The briquets were hard and showed no water cracks, although the coal was very wet.

The briquets made were delivered to the Chesapeake & Ohio Railway for trial under locomotive boilers. For results of the locomotive steaming tests see pages 114 and 115.

Briquetting tests.

	Test 280.	Test 281.
Size as used:		
Over $\frac{1}{4}$ inch ... per cent	0.1	0.0
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch ... do	8.9	5.1
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch ... do	27.1	28.6
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch ... do	27.0	32.8
Through $\frac{1}{40}$ inch ... do	36.9	33.5
Details of manufacture:		
Machine used	English.	Renfrow No. 2.
Briquetting temperature ... °F	187	190
Binder—		
Kind	W. G. P.	W. G. P.
Laboratory No	5941	5941
Amount ... per cent	6	6
Weight of—		
Fuel briquetted ... pounds	65,800	300,000
Briquets, average ... do	3.57	0.720
Moisture in briquet mixture ... per cent	7.04	6.87
Drop test (1-inch screen):		
Held ... do	19.6	....
Passed ... do	80.4	....
Tumbler test (1-inch screen):		
Held ... do	48.8	....
Passed ... do	51.2	....
Fines through 10-mesh sieve ... do	88.9	....
Weather test:		
Time exposed ... days	137	125
Condition	B	B
Absorption test:		
Time immersed ... days	5	11
Water absorbed ... per cent	7.87	12.01
Average for first 4 days ... do	1.95	2.92
Specific gravity (apparent)	1.185	1.079

Chemical analyses of coal and briquets.

	Raw fuel.	Test 280.	Test 281.
Laboratory No	5774	5857	5859
Proximate:			
Moisture ... per cent	3.80	1.09	3.21
Volatile matter ... do	21.32	18.70	19.49
Fixed carbon ... do	67.30	73.60	72.67
Ash ... do	7.58	6.61	4.63
Sulphur ... do	.58	.95	.68
Ultimate:			
Hydrogen ... do	4.56	4.63	4.62
Carbon ... do	82.14	81.77	84.69
Nitrogen ... do	1.36	1.21	1.31
Oxygen ... do	3.46	4.75	3.90

Extraction analyses.

	Pitch.	Fuel, J-15.	Briquets.	
			Test 280.	Test 281.
Laboratory No	5941	5774	5857	5859
Air-drying loss ... per cent	....	3.00	0.40	2.50
Extracted by CS_2 (as received) ... do	98.44	0.42	5.54	5.77
Pitch in briquet by analysis ... do	....	....	5.22	5.46
Heat value ... B. t. u.	16,978	14,009	14,548	14,575

WEST VIRGINIA—JAMESTOWN NO. 16.

The sample designated Jamestown No. 16 consisted of semibituminous run-of-mine coal from West Virginia.

The coal was briquetted with four different kinds of water gas pitch binders, 6 per cent of each being used. Seemingly the best briquets were those of test 285, although those of test 282 were practically as good. Both of these tests were made on the English machine. Test 283, made on the Renfrow No. 2 machine, produced satisfactory briquets, but the briquets made on the English machine with water-gas pitch in test 284 (Lab. No. 5939) were not satisfactory, as they did not stand the physical tests well.

Tests 283 and 285 made briquets with smooth, firm, fine-grained surfaces; they broke with difficulty, and had firm and hard fracture surfaces.

Test 282 made good briquets as far as strength was concerned, but their surfaces were rough and coarse-grained, and their edges rubbed off somewhat easily. They broke with difficulty, and the fracture surface was coarse, firm, and dull-black in color.

Test 284 furnished very poor briquets, the surfaces of which were rubbed off easily, owing either to too small a percentage of pitch or to too low a briquetting temperature; the briquets were easily broken, and the fractured surfaces were rough and easily rubbed off.

The entire sample was made into briquets and delivered to the Atlantic Coast Line Railway Co. for locomotive tests, coal from the same locality being regularly used by the engines on that road.

A brief description of the locomotive steaming tests and results is to be found under the heading "Locomotive-boiler Tests."

Briquetting tests.

	Test 282.	Test 283.	Test 284.	Test 285.
Size as used:				
Over $\frac{1}{4}$ inch ... per cent..	5.0	0.1		
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch ... do....	16.0	14.4		
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch ... do....	31.4	36.0		
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch ... do....	26.3	25.9		
Through $\frac{1}{40}$ inch ... do....	21.3	23.6		
Details of manufacture:				
Machine used	English.	Renfrow No. 2.	English.	Renfrow No. 2.
Briquetting temperature ... °F..	174	189		
Binder—				
Kind	W. G. P.	W. G. P.	W. G. P.	W. G. P.
Laboratory No.	4879	5941	5939	5940
Amount ... per cent..	6	6	6	6
Weight of—				
Fuel briquetted ... pounds..	52,048	66,000	30,600	37,400
Briquets, average ... do....	4.10	0.641	3.83	3.68
Moisture in briquet mixture ... per cent..	9.55	7.55		8.40
Drop test (1-inch screen):				
Held ... do....	77.3	35.5	39.2	78.8
Passed ... do....	22.7	64.5	60.8	21.2
Tumbler test (1-inch screen):				
Held ... do....	82.7	56.0	47.8	82.8
Passed ... do....	17.2	44.0	52.2	17.2
Fines through 10-mesh sieve ... do....	88.0	90.1	90.1	89.5
Weather test:				
Time exposed ... days..	137	125	118	118
Condition	B	B	B	A
Absorption test:				
Time immersed ... days..	31	31	31	31
Water absorbed ... per cent..	9.79	10.55	15.98	11.23
Average for first 4 days ... do....	0.89	1.12	1.82	1.13
Specific gravity (apparent)	1.206	1.126	1.112	1.143

Chemical analyses of coal and briquets.

	Raw fuel.	Test 282.	Test 283.	Test 284.	Test 285.
Laboratory No	5825	5946	5945	5947	5853
Proximate:					
Moisture ... per cent	4.89	2.21	2.27	2.06	8.40
Volatile matter ... do	29.63	30.97	32.56	31.65	....
Fixed carbon ... do	57.74	52.97	56.52	58.74	....
Ash ... do	7.74	13.85	8.65	7.55	....
Sulphur ... do	.72	.89	.85	.80	....
Ultimate:					
Hydrogen ... do	4.69	4.27	4.67	4.69	....
Carbon ... do	77.63	71.89	77.73	78.27	....
Nitrogen ... do	1.27	1.11	1.25	1.27	....
Oxygen ... do	7.51	7.66	6.63	7.24	....

Extraction analyses.

	Pitches.				Fuel, J-16.	Briquets.			
						Test 282.	Test 283.	Test 284.	Test 285.
Laboratory No	4879	5939	5940	5941	5825	5946	5945	5947	5853
Air-drying loss ... per cent	....	....	....	....	3.40	1.20	1.40	1.20	7.00
Extracted by CS_2 (as received) ... per cent	94.50	98.13	98.60	98.44	0.68	5.43	6.39	5.10	....
Pitch in briquet by analysis, per cent	....	....	....	....	....	5.06	5.84	4.54	....
Heat value ... B. t. u.	16,805	16,781	16,780	16,978	13,480	12,780	13,754	13,939	....

WEST VIRGINIA—JAMESTOWN NO. 17.

The sample designated Jamestown No. 17 consisted of semibituminous run-of-mine coal from the Pocahontas No. 3 bed of West Virginia, and was tested at the Norfolk plant.

Eighty tons of this coal was briquetted for a special test on the battleship *Connecticut* of the United States Navy, and as it was shipped without any samples being retained, no data exist on which to make a report.

Briquetting tests.

	Test 288.
Details of manufacture:	
Machine used	American.
Binder—	
Kind	W. G. P.
Laboratory No	5940
Amount ... per cent	6
Weight of fuel briquetted ... pounds	160,000

Chemical analyses.

	Raw fuel.		Raw fuel.
Laboratory No	5832	Ultimate:	
Proximate:		Hydrogen ... per cent	4.28
Moisture ... per cent	3.16	Carbon ... do	87.01
Volatile matter ... do	15.90	Nitrogen ... do	1.00
Fixed carbon ... do	76.73	Oxygen ... do	2.72
Ash ... do	4.31		
Sulphur ... do	.52		

Extraction analyses.

		Pitch.	Fuel, J-17.
Laboratory No.		5940	5832
Air-drying loss	per cent.	....	2.80
Extracted by CS_2 (as received)	do.	96.60	....
Heat value	B. t. u.	16,780	14,746

WYOMING NO. 1.

A sample of black lignite coal (over a 5-inch screen) from near Sheridan, Sheridan County, on the Burlington system, was designated Wyoming No. 1, and a part of the sample was subjected to briquetting tests on the English machine at the St. Louis plant.

This coal was a black, pitchy-looking lignite, which contained 23 per cent of water. It was first tried without drying, 9 per cent of pitch H being used. Judging from the resulting briquets there was a slight excess of pitch, but on account of the large proportion of water in the lignite the pitch seemingly failed to adhere to the grains of lignite. The fresh briquets did not stand handling well, and when broken open the grains of lignite seemed to be coated with moisture, which prevented the pitch from adhering to them. Many of the briquets were porous, not being sufficiently pressed, and they were also brittle. Some of them, however, were fairly good. When broken and burned in the stove they stood up well in the fire and burned better than any lignite briquets that had thus far been made. They weighed on an average 6.31 pounds each.

Another ton of this lignite was ground in the Williams mill and run through the drier, but this operation removed only a part of the water, so that the briquets still contained considerable moisture. This material was briquetted on the English machine with 8 per cent of pitch H. A minimum amount of steam was used, which did not contain any excess of water, and a maximum pressure was applied. As received from the machine, many of the briquets showed perpendicular cracks, due to excessive pressure. The hot briquets did not stand handling, the individual grains of the lignite seeming to be wet and not cohering at all. Many of them would crack badly under their own weight. On breaking open the hot briquets the grains of lignite seemed to move about as if alive. This lack of cohesion continued until the pitch became rather hard and could not longer be pressed in the machine. Variation in the pressure of steam used as the mixture passed through the pug mill had no effect on the cohesion of the briquets. On cooling, however, these briquets became very hard and strong and broke with a sharp fracture and with only a small waste. In burning they did not fall to pieces, as did the other lignite briquets, but burned satisfactorily. They were very light, weighing only 5.85 pounds each, and had a specific gravity of 0.98. The specific gravity of the coal was only 1.16. The crushing strength of these briquets was 9,600 pounds, or 339 pounds to the square inch.

Another ton of this coal was tested with a soft, tough asphalt, B6, from Casper, Wyo. As had been shown by laboratory tests, this asphalt could not be used alone on the English machine, and as a result the lignite was briquetted with 5 per cent of asphalt B6, 2½ per cent of rosin, and 1 per cent of lime that had previously been hydrated. The mixture worked perfectly in the machine, and the hot briquets were firm and easily handled, but the proportion of binder was not sufficient, and the briquets were dry and not strong. Another reason for this result was that during the two crushings and dryings of the lignite the grains had become of a nearly uniform size (about 10-mesh fineness), so that the briquets were very porous in spite of the maximum pressure used. In burning, the briquets fell to pieces. They weighed on an average 5.40 pounds each. A combination of this coal and asphalt can undoubtedly be obtained that will briquet satisfactorily.

A further test of this lignite was made with 7 per cent of a mixture composed of 20 parts asphalt and 1 part rosin, with 1 part slaked lime. The coal had been previously dried. The briquets were poor and disintegrated badly in the fire. This coal was again tried with the same binder without previous drying. The resultant briquets, though better physically, did not have so much cohesion in the fire as the first. It is probable that a partial drying of this lignite would give the best results.

A supply of Wyoming lignite received from Casper, Wyo., was briquetted without previous drying with 8 per cent of a mixture composed of 2 parts of Wyoming asphalt to 1 part of rosin and 1 per cent of slaked lime. The resultant briquet stood up in the fire fairly well, although it disintegrated a little. With 7 per cent of the mixture and 1 per cent of slaked lime the briquet was practically the same; with 6 per cent of the mixture and 1 per cent of slaked lime the briquet was crumbly; and with 7 per cent of the mixture without lime the briquet was physically a little tougher, but disintegrated more in the fire than when the lime was used. On increasing the percentage of lime and using 7 per cent of the mixture and 2 per cent of slaked lime a briquet was obtained that looked much like those made with the 7 to 1 combination and was not any stronger.

Chemical analysis of subbituminous coal from Sheridan, Wyo.

	Car sample.		Car sample.
Laboratory No.	1479	Ultimate:	
Proximate:		Hydrogen, per cent	5.01
Air-drying loss, per cent	6.00	Carbon, do.	70.97
Moisture, do.	22.63	Nitrogen, do.	1.32
Volatile matter, do.	35.68	Oxygen, do.	16.12
Fixed carbon, do.	37.19	Heat value, B. t. u.	9,734
Ash, do.	4.50		
Sulphur, do.	.59		

WYOMING NO. 6.

Subbituminous run-of-mine coal from 3 miles west of Kemmerer, Lincoln County, 2 miles from the Union Pacific Railroad, was designated Wyoming No. 6, and a part (24,000 pounds) of the sample was used in briquetting test 134. Steaming test 419 was made of the briquets from the above test.

In test 134 the details were as follows: Size of coal used: Over one-fourth inch, 2.4 per cent; one-tenth inch to one-fourth inch, 9.2 per cent; one-twentieth inch to one-tenth inch, 22.2 per cent; one-fortieth inch to one-twentieth inch, 26 per cent; through one-fortieth inch, 40.2 per cent; kind of binder, water-gas pitch; laboratory number, 3486.

English briquets, with an average weight of 3.18 pounds, and made at 179° F., with 5, 6, 7, 8, and 10 per cent of binder, would not cohere; all the briquets could be crushed in the hand. In the weathering test they were exposed 180 days; the condition of those with 5 and 6 per cent of binder was D; of those with 7 and 8 per cent binder, E.

Drop test (1-inch screen).

	Percentage of binder.			
	5	6	7	8
Held	35.4	61.3	74	79
Passed	64.6	38.7	26	21

Renfrow No. 1 machine briquets made at 149° F., average weight 0.42 pound, with 7, 8, and 10 per cent binder, were not improved by an increase in the percentage of pitch; all of the briquets were poor and could be crushed in the hand. In the weathering test they were exposed 180 days when their condition was E.

Chemical analyses of coal and briquets.

	Car sample.	Test 134.		Car sample.	Test 134.
Laboratory No	3390	....	Ultimate:		
Proximate:			Hydrogen...... per cent	5.31	4.99
Moisture........per cent	19.00	15.57	Carbon..........do	73.31	74.59
Volatile matter......do	36.64	38.74	Nitrogen..........do	1.21	1.03
Fixed carbon......do	41.24	42.87	Oxygen..........do	15.72	15.35
Ash..........do	3.12	2.82			
Sulphur..........do	.49	.59			

Extraction analyses.

	Pitch.	Fuel.	Briquets.
		Wyo. No. 6.	Test 134.
Laboratory No	3486	3390	....
Air-drying loss..........per cent	....	11.30	4.90
Extracted by CS_2 (as received)..........do	85.57	0.83	5.82
Pitch in briquet by analysis..........do	....	....	6.13
Heat value..........B. t. u	16,407	10,307	10,994

MISCELLANEOUS NO. 5.

A sample of coke breeze furnished by a gas company was used in briquetting test 152 and, in mixture with Tennessee No. 4, in tests 150 and 151. The data of briquetting tests Nos. 150 and 151 are included under the discussion of Tennessee No. 4.

In test 152 the size of coal used was as follows: Over one-fourth inch, 2.8 per cent; one-tenth inch to one-fourth inch, 11 per cent; one-twentieth inch to one-tenth inch, 21.2 per cent; one-fortieth inch to one-twentieth inch, 30.4 per cent; through one-fortieth inch, 34.6 per cent. The briquets were very soft when warm, showing nearly 25 per cent breakage in falling from the delivery belt of the machine and in handling with coke forks. They could not be piled satisfactorily while warm. When cold they had a rough, hard surface, with a coating of brown from the dies, and broke without crumbling, giving a rough fracture surface.

Briquetting tests.

	Test 152.		Test 152.
Details of manufacture:		Tumbler test (1-inch screen):	
Machine used	Renfrow No. 1	Held ... per cent	72.5
Briquetting temperature. ° F	149	Passed ... do	27.5
Binder—		Fines through 10-mesh sieve, per cent	90.0
Kind	W. G. P.	Weather test:	
Laboratory No	3410	Time exposed ... days	198
Amount ... per cent	8	Condition	A
Weight of—		Absorption test:	
Fuel briquetted .. pounds	20,000	Time immersed ... days	15
Briquet, average ... do	0.437	Water absorbed ... per cent	20.6
Drop test (1-inch screen):		Average for first 5 days .. do	2.64
Held ... per cent	60.5	Specific gravity (apparent)	1.030
Passed ... do	39.5		

Chemical analyses of coal and briquets.

	Fuel.	Test 152.		Fuel.	Test 152.
Laboratory No	3386	3385	Fixed carbon ... per cent	73.25	72.05
Moisture ... per cent	10.72	5.01	Ash ... do	11.95	12.24
Volatile matter ... do	4.08	10.70	Sulphur ... do	1.02	1.05

Extraction analyses.

	Pitch.	Fuel.	Briquets, test 152.
Laboratory No	3410	3386	3385
Air-drying loss ... per cent		8.80	3.10
Extracted by CS_2 (as received) ... do	79.98	0.59	6.74
Pitch in briquet by analyses ... do			7.75
Heat value ... B. t. u.	16,478	11,036	12,119

MISCELLANEOUS NO. 9.

Coke breeze from a plant in Madison, Ill., was designated Miscellaneous No. 9 and was used in briquetting tests 247 and 249; also, in mixture with Pennsylvania No. 18, in briquetting tests 238, 239, 240, and 248. The briquets from test 247 were used in a special cupola test. A description and data from tests 238, 239, 240, and 248 are found under the heading "Pennsylvania No. 18."

In test 247 the size of coal used was as follows: Over one-fourth inch, 2.2 per cent; one-tenth inch to one-fourth inch, 8 per cent; one-twentieth inch to one-tenth inch, 15 per cent; one-fortieth inch to one-twentieth inch, 25.6 per cent; through one-fortieth inch, 49.2 per cent. Attempts to briquet coke breeze with unslaked lime as a binder were unsatisfactory. Briquets were made by the addition of pitch to the lime, and showed when warm characteristics similar to those of the briquets made in test 249. The cold briquets, however, were much harder and continued to increase in hardness for several weeks. The hardened briquets had a smooth outer surface and a rough, hard fracture surface, with firm edges.

In test 249 the size of coal used was as follows: Over one-fourth inch, 1.6 per cent; one-tenth inch to one-fourth inch, 7.6 per cent; one-twentieth inch to one-tenth inch, 15.8 per cent; one-fortieth inch to one-twentieth inch, 25.8 per cent; through one-fortieth inch, 49.2 per cent. The characteristics of these briquets were similar to those of the briquets discussed in the report of test 248. The briquets had a coating of bronze from the dies, which showed perceptibly the erosive effect of the coke. Satisfactory briquets were made with 8 per cent of binder, and no increase in cohesion was observed when more were used.

Briquetting tests.

	Test 247.[a]	Test 249.
Details of manufacture:		
Machine used	Renfrow No. 1.	Renfrow No. 1.
Briquetting temperature °F.	176	158
Binder—		
Kind	(b)	W. G. P.
Laboratory No.	4879	4879
Amount per cent.	8 of each.	8
Weight of—		
Fuel briquetted pounds.	6,000	2,000
Briquet, average do.	0.642	0.520
Drop test (1-inch screen):		
Held per cent.	66.0	67.0
Passed do.	34.0	33.0
Tumbler test (1-inch screen):		
Held do.	86.5	79.5
Passed do.	13.5	20.5
Fines through 10-mesh sieve do.	65.0	81.0
Absorption test:		
Time immersed days.	10	23
Water absorbed per cent.	10.0	18.8
Average for first—		
6 days do.	1.50	....
5 days do.	....	2.60
Specific gravity (apparent)	1.287	1.178

[a] The briquets made in this test were used in a special cupola test.
[b] Water-gas pitch and unslaked lime, 8 per cent each.

Chemical analyses of coal and briquets.

	Raw fuel.	Tests 247 and 249.		Raw fuel.	Tests 247 and 249.
Laboratory No.	4763	4827	Fixed carbon per cent.	75.50	58.55
Moisture per cent.	1.95	2.61	Ash do.	21.66	28.13
Volatile matter do.	.89	10.71	Sulphur do.	.66	.98

Extraction analyses.

	Pitch.	Fuel.	Briquets, tests 247 and 249.
Laboratory No	4879	4763	4827
Air-drying loss ... per cent		1.30	1.30
Extracted by CS_2 ... do	94.50	0.15	7.22
Pitch in briquet by analysis ... do			7.50
Heat value ... B. t. u.	16,805	10,870	9,925

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